WHITE PAPER

USDA Forest Service Pacific Northwest Region Umatilla National Forest

WHITE PAPER F14-SO-WP-SILV-36

Stand Density Protocol for Mid-Scale Assessments[1]

David C. Powell; Forest Silviculturist
Supervisor's Office; Pendleton, OR

Initial Version: **MARCH 2001**
Most Recent Revision: **FEBRUARY 2013**

INTRODUCTION

Tree density needs to be determined before deciding if a forest polygon is overstocked. It can be characterized using stand density index or another measure of relative density, or as trees per acre, basal area per acre, wood volume, canopy cover or any number of similar measures (Curtis 1970, Ernst and Knapp 1985).

Tree density varies in response to at least three factors.

[1] White papers are internal reports; they receive only limited review. Viewpoints expressed in this paper are those of the author – they may not represent positions of the USDA Forest Service.

1. Potential vegetation is an indicator of "carrying capacity" for tree density (moist sites can support more density than dry sites). It controls the rate at which forests produce and accumulate density – how fast existing trees grow and how quickly new trees get established. Consider two examples of how potential vegetation affects tree density:
   a. On the ponderosa pine/bluebunch wheatgrass plant association, a fully-stocked ponderosa pine stand supports 133 trees per acre at a quadratic mean diameter of 10 inches;
   b. On the grand fir/twinflower plant association, a fully-stocked ponderosa pine stand supports 365 trees per acre at a quadratic mean diameter of 10 inches (Powell 1999).

2. Species composition has an important influence on density relationships because shade-tolerant trees can tolerate high density levels better than shade-intolerant tree species (Cochran et al. 1994).

3. Disturbance processes regulate density by periodically killing trees and maintaining stocking levels within a range of variability that differs for each combination of species and plant association (Cochran et al. 1994).

   Fire, insects and other disturbance agents reduce tree density and modify stocking levels; Armillaria root disease, Douglas-fir beetle, Douglas-fir tussock moth, fir engraver, Indian paint fungus, mountain pine beetle, spruce beetle, western pine beetle and western spruce budworm all seem to respond positively to high tree density (Powell 1999).

This protocol was designed to help assess tree density and stocking levels for use with mid-scale analysis processes (REO 1995). Specifically, it addresses two primary objectives:

1. Quantify four stocking thresholds (lower limit of the management zone, upper limit of the management zone, full stocking, maximum density) for two potential vegetation units (plant association groups, potential vegetation groups) and using four traditional forestry metrics (stand density index, trees per acre, basal area per acre, canopy cover percentage).
2. Provide database queries for calculating three tree density ratings (high, moderate, low) for three stand size classes (seedlings/saplings, poles, small trees), two potential vegetation units (plant association groups, potential vegetation groups) and using three traditional forestry metrics (trees per acre, basal area per acre, canopy cover percentage).

DEVELOPING AN ANALYSIS PROTOCOL

A protocol is valuable for producing long-term data sets of known quality; protocols help provide information to meet the agency's business requirements and program objectives. This protocol establishes standards and procedures relating to density and stocking assessment for mid-scale analysis areas.

Suggested stocking levels for the Blue Mountains were initially developed by Cochran et al. (1994). They account for potential vegetation because stocking levels differ by plant association, and they account for tree species composition because stocking levels differ for each of seven conifer species.

Powell (1999) expanded the Cochran et al. (1994) stocking information by expressing it as trees per acre, basal area per acre, canopy cover and equilateral tree spacing, and by calculating these metrics for a variety of tree sizes ranging from 1 inch to 30 inches diameter.

For this mid-scale protocol, the plant associations included in Cochran et al. (1994) and Powell (1999) were aggregated into two potential vegetation hierarchical units – plant association groups (PAGs) and potential vegetation groups (PVGs). The protocol for assigning potential vegetation types to PAGs and PVGs is described in Powell et al. (2006).

Any stocking analysis is species dependent. Some tree species are more sensitive to overcrowding than others and this is clearly evident when examining the suggested stocking levels provided by Cochran et al. (1994) and Powell (1999).

For this mid-scale protocol, the seven conifer species included in Cochran et al. (1994) and Powell (1999) were also included here when presenting the stocking thresholds in tables 1-3 and tables 7-9.

For the database queries (tables 4-6 and 10-12), a “limiting species” approach was used by assuming that the tree species with the lowest stocking level has the most restrictive growing-space requirements, and that other species with less exacting requirements will develop acceptably under the lower stocking levels established for the most limiting species.

Stand density index (SDI) is a relative density measure that does not vary by tree size. When converting from SDI to other traditional forestry metrics such as basal area, it was necessary to vary the suggested stocking levels slightly by tree size. Note that Powell (1999) explains why this variation is necessary (see “basal area considerations” on page 18 in Powell 1999).

To account for these size class variations, the database queries (tables 4-6 and 10-12) were stratified using three size class categories (seedlings/saplings, poles, small trees).

STAND DENSITY INDEX

Stand density index (SDI) expresses the relationship between a number of trees per acre and a quadratic mean diameter (QMD); SDI is indexed to a QMD of 10 inches (Daniel et al. 1979, Reineke 1933). This means that an SDI of 140 can be the same as 140 trees per acre but only when a stand’s QMD is 10 inches; at any other QMD, the density associated with an SDI of 140 would be something other than 140 trees per acre.

For this mid-scale protocol, the specific SDI values for each combination of plant association and tree species from Powell (1999) were entered into a spreadsheet, and averages were then computed for ten plant association groups and three potential vegetation groups.

Table 1 shows the stand density index (SDI) values associated with four stocking thresholds, seven conifer species and three potential vegetation groups. Table 7 provides the same information as table 1 except it includes plant association groups instead of potential vegetation groups.

TREES PER ACRE

This metric is an absolute measure of tree density per unit area. In ecological studies, tree density is generally more useful than canopy cover for characterizing species abundance because two tree species could have the same canopy cover percentage but one occurs as many small individuals (high density) whereas the other has relatively few large individuals (low density).

Stem density is often considered to be the most efficient metric when comparing individuals in the same lifeform (trees with trees, tall shrubs with tall shrubs, etc.). Conversely, stem density is probably inappropriate when comparing divergent lifeforms (comparing the density of trees and forbs in a plant community, for example).

Powell (1999) describes how the stand density index values from Cochran et al. (1994) were converted into trees per acre. For this mid-scale protocol, the specific trees per acre values for each combination of plant association and tree species from Powell (1999) were entered into a computerized spreadsheet, and averages were then computed for ten plant association groups and three potential vegetation groups.

Table 1 shows the "trees per acre" values associated with four stocking thresholds, seven conifer species and three potential vegetation groups. Table 7 provides the same information as table 1 except it includes plant association groups instead of potential vegetation groups. **Note that the values in tables 1 and 7 are a "trees per acre" stocking level for stands with a quadratic mean diameter of 10 inches only.**

Table 4 provides "trees per acre" database queries for three tree density categories (low, moderate, high), three stand size classes (seedlings/saplings, poles, small trees) and three potential vegetation groups. Table 8 provides the same information as table 4 except it includes plant association groups instead of potential vegetation groups.

BASAL AREA PER ACRE

Basal area refers to the cross-sectional area of a tree (in square inches) above a specified break-point diameter; the "basal area per acre" metric sums individual values for all of the trees on an acre. Foresters use basal area when prescribing density management treatments and it is sometimes used in ecological studies as a measure of species dominance.

Powell (1999) describes how the stand density index values from Cochran et al. (1994) were converted into basal area per acre. For this mid-scale protocol, the specific basal area per acre values for each combination of plant association and tree species from Powell (1999) were entered into a computerized spreadsheet, and averages were then computed for ten plant association groups and three potential vegetation groups.

Table 2 shows the basal area per acre values associated with four stocking thresholds, seven conifer species and three potential vegetation groups. Table 8 provides the same information as table 2 except it includes plant association groups instead of potential vegetation groups.

Table 5 provides “basal area per acre” database queries for three tree density categories (low, moderate, high), three stand size classes (seedlings/saplings, poles, small trees) and three potential vegetation groups. Table 9 provides the same information as table 5 except it includes plant association groups instead of potential vegetation groups.

CANOPY COVER PERCENTAGE

Canopy cover is a density metric used extensively in ecological studies. It is defined as the vertical projection of vegetation foliage onto the ground surface when viewed from above. Canopy cover has limitations when compared with other forest density measures (see the “trees per acre” section).

Powell (1999) describes how the stand density index values from Cochran et al. (1994) were converted into canopy cover percentages. For this mid-scale protocol, the specific canopy cover percentages for each combination of plant association and tree species from Powell (1999) were entered into a computerized spreadsheet, and averages were then computed for ten plant association groups and three potential vegetation groups.

Table 3 shows the canopy cover percentages associated with four stocking thresholds, seven conifer species and three potential vegetation groups. Table 9 provides the same information as table 3 except it includes plant association groups instead of potential vegetation groups.

Table 6 provides “canopy cover percentage” database queries for three tree density categories (low, moderate, high), three stand size classes (seedlings/saplings, poles, small trees) and three potential vegetation groups. Table 10 provides the same information as table 6 except it includes plant association groups instead of potential vegetation groups.

Table 13 provides all four forestry metrics (stand density index, trees per acre, basal area per acre and canopy cover percentage), by plant association group, for two silviculturally relevant stocking thresholds – the lower and upper limits of the management zone.

Table 14 provides the same information as table 13 except it includes potential vegetation groups instead of plant association groups.

Note: figures 4-12 (located at end of this document before the glossary) provide suggested stocking levels (trees/acre, basal area/acre, canopy cover) for three potential vegetation groups, a range of quadratic mean diameters, a mixed composition, and an irregular stand structure.

LOWER LIMIT OF THE MANAGEMENT ZONE (FIG. 2)

This stocking threshold is referred to as the "lower limit of full site occupancy" in figure 1. Since the lower limit of the management zone is described in Cochran et al. (1994) and Powell (1999), it is not discussed here.

UPPER LIMIT OF THE MANAGEMENT ZONE (FIG. 2)

This stocking threshold is referred to as the "lower limit of self-thinning zone" in figure 1. Since the upper limit of the management zone is described in Cochran et al. (1994) and Powell (1999), it is not discussed here.

FULL STOCKING (FIG. 2)

This stocking threshold is referred to as "normal density" in figure 1. Full stocking is also called "average-maximum" density because it is analogous to a least-squares regression line for scatter plot data collected from fully-stocked stands (fig. 3). Since full stocking is described in Cochran et al. (1994) and Powell (1999), it is not discussed here.

MAXIMUM DENSITY (FIG. 1)

When L.H. Reineke developed stand density index (Reineke 1933), he plotted tree densities for fully stocked, even-aged stands and then drew a freehand line that skimmed the outermost data values (fig. 3). This outermost boundary line represented maximum density for each tree species for which he had data.

Cochran et al. (1994) and Powell (1999) describe full stocking in great detail but neither source quantifies maximum density. Powell (1999), however, refers to maximum density and notes that maximum density is easily calculated when full stocking is known.

This means that Cochran et al. (1994) and Powell (1999) provide all of the information needed to calculate maximum density:

1. Powell (1999) states that maximum density can be calculated as 125% of full stocking (see table 3 on page 15 in Powell 1999);
2. Cochran et al. (1994) provide species-wide values of full stocking for each of seven conifer species occurring in the Blue Mountains (see table 1 on page 3 in Cochran et al. 1994); and
3. Cochran et al. (1994) and Powell (1999) provide full stocking values for each combination of plant association and tree species occurring in the Blue-Ochoco and Wallowa-Snake physiographic provinces (see tables 3 and 4 in Cochran et al. 1994).

Maximum density is included because it is a useful metric for forest dynamics modeling using the Forest Vegetation Simulator (it is used with the SDIMAX keyword, for example).

The chart below summarizes species-wide values of full stocking, and their corresponding values of maximum density, for the seven tree species included in Cochran et al. (1994).

Tree Species	Species-wide Full Stocking[1]	Maximum Density[2]
Ponderosa pine	365	456
Interior Douglas-fir	380	475
Western larch	410	512
Lodgepole pine	277	346
Engelmann spruce	469	586
Grand fir	560	700
Subalpine fir	416	520

[1] Species-wide full stocking values for the Blue Mountains are the SDIn values from table 1 in Cochran et al. (1994).

[2] Maximum density was calculated as 125% of maximum full stocking (see table 3 in Powell 1999).

Table 15 (located near the end of this report) provides maximum density values for combinations of tree species and plant association occurring on the Umatilla National Forest.

CAUTIONS AND CAVEATS

No protocol can address every contingency. Please consider these potential limitations when using the protocol described in this paper.

1. Early-seral species were generally selected to represent a PVG or PAG for the database query tables, implying either that late-seral species (spruce, firs) do not exist or that they would be preferentially removed during a density management treatment (thinning, etc.).
2. Only one tree species was selected to represent a PVG or PAG for the database query tables, implying either that mixed-species stands do not exist or that a mixed composition would be discriminated against during a density management treatment. **Response:** Selecting a single species to represent a PVG or PAG was a simplifying assumption necessary for a mid-scale protocol; it is not implied that an operational treatment (such as a thinning project) would be designed for just a single tree species.
3. The database query tables (4-6 and 10-12) use the management zone concept; the low category corresponds to the lower limit of the management zone, the moderate category refers to the management zone, and the high category corresponds to the upper limit of the management zone. Some users might find this range of stocking levels to be too conservative.

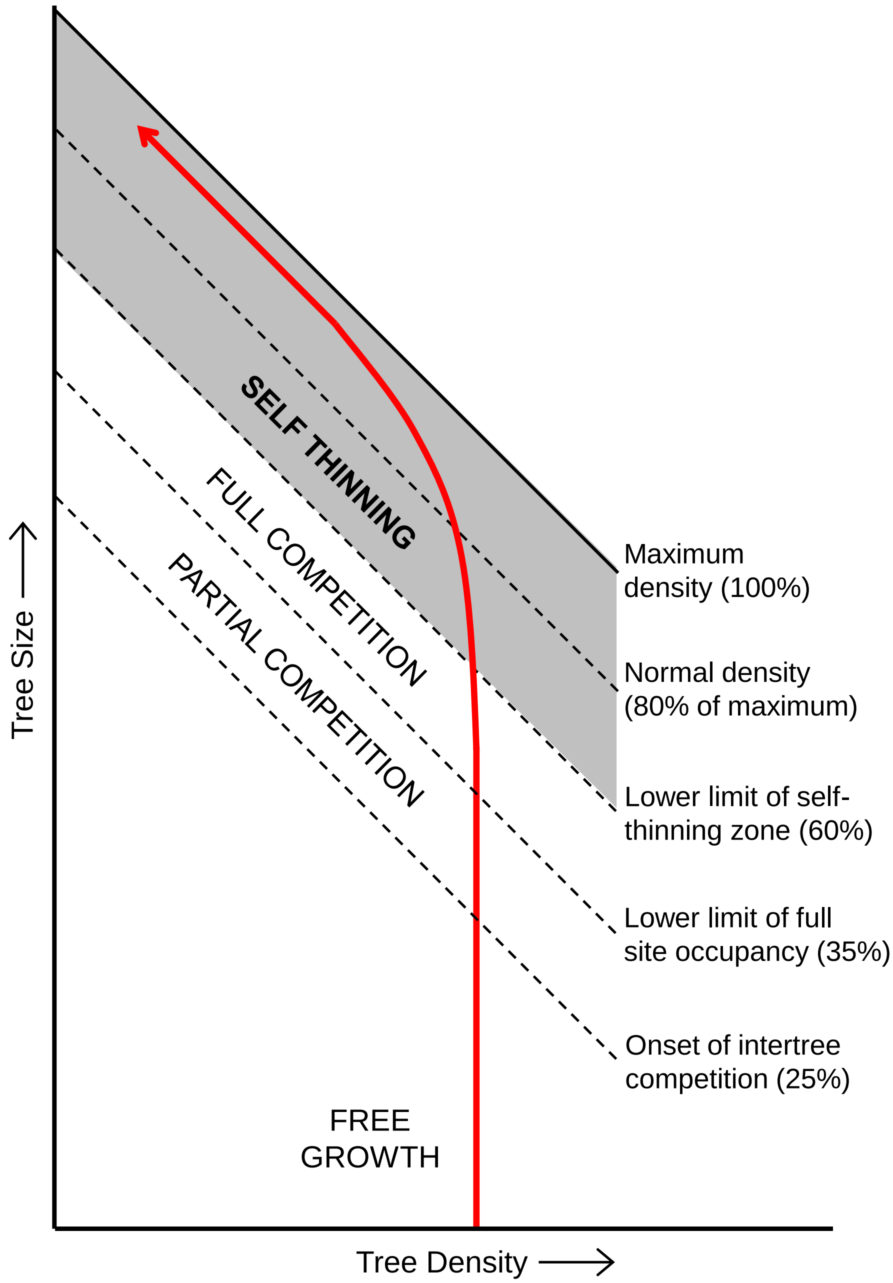

Figure 1 – Stand development as related to maximum density. Initially, trees do not use all of a site's resources during a period of free growth (no intertree competition occurs). When roots and crowns begin to interact, the "onset of intertree competition" threshold has been reached. As growth continues through a partial-competition zone, trees capture all growing space and the "lower limit of full site occupancy" threshold is breached. Full competition now occurs between trees. As competition intensifies, stands enter a self-thinning zone (gray shading) by crossing the "lower limit of self-thinning zone" threshold. In the self-thinning zone, a tree only increases in size after one or more neighboring trees relinquish their growing space by dying. Many trees are dying as the stand passes the "normal density" threshold and approaches maximum density. Maximum density is shown as a solid line because it is an absolute threshold. Maximum density is used as a reference level for this relative density system.

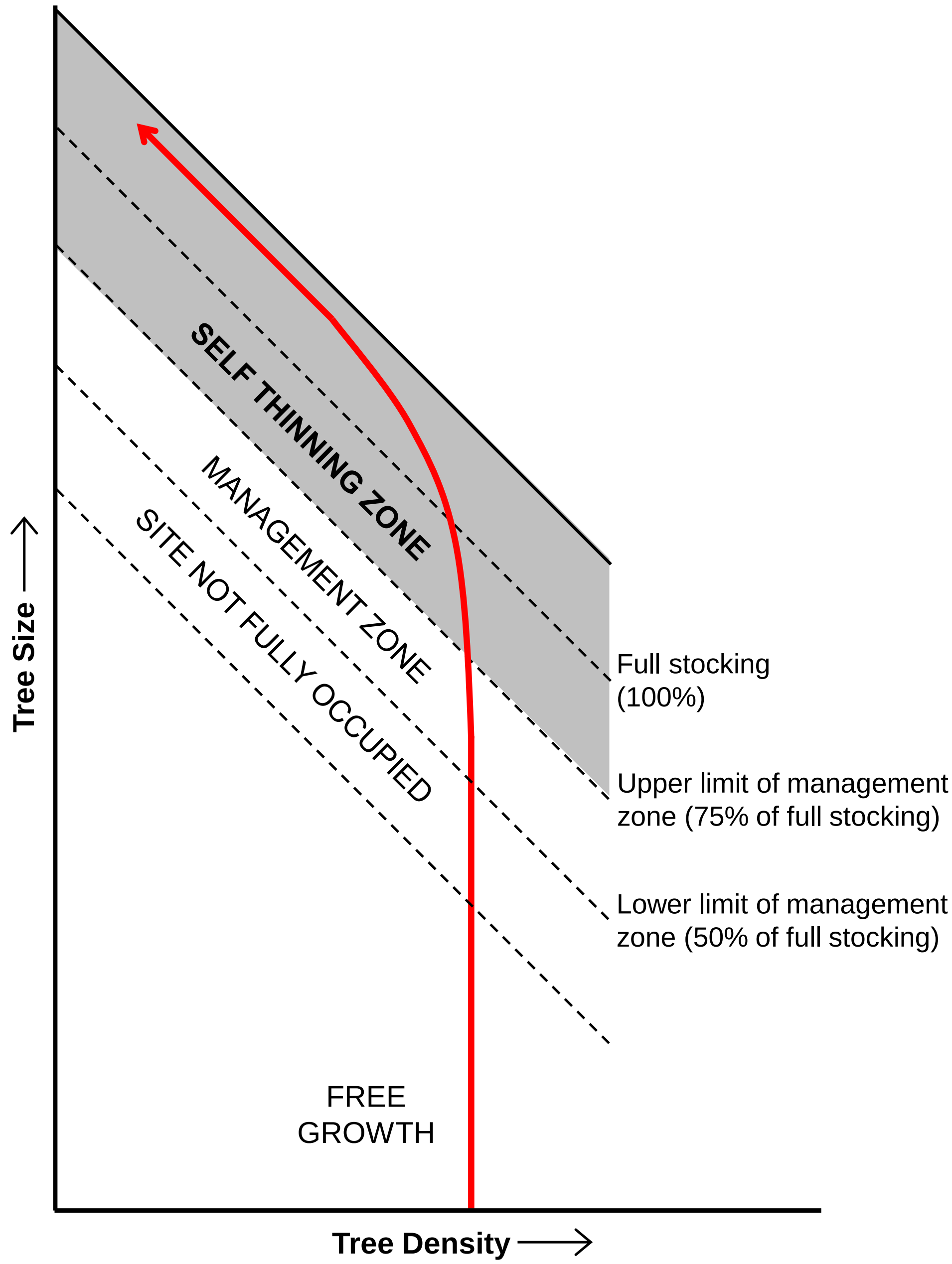

Figure 2 – Stand development as related to full stocking. When Cochran et al. (1994) published suggested stocking levels, they quantified the "full stocking" level for combinations of upland-forest plant association and tree species for northeastern Oregon and southeastern Washington (Johnson and Clausnitzer 1992, Johnson and Simon 1987). When comparing this figure and figure 1, you will note that: (1) the Cochran paper did not include "maximum density;" (2) the "normal density" in fig. 1 is called full stocking here (although the names vary, this is the same stocking level); (3) the "lower limit of the self-thinning zone" in fig. 1 was used as the "upper limit of the management zone" in the Cochran paper; (4) the "lower limit of full site occupancy" in fig. 1 was used as the "lower limit of the management zone" in the Cochran paper; (5) the Cochran paper did not include the "onset of intertree competition" threshold; and (6) the Cochran paper used full stocking as a reference level instead of maximum density.

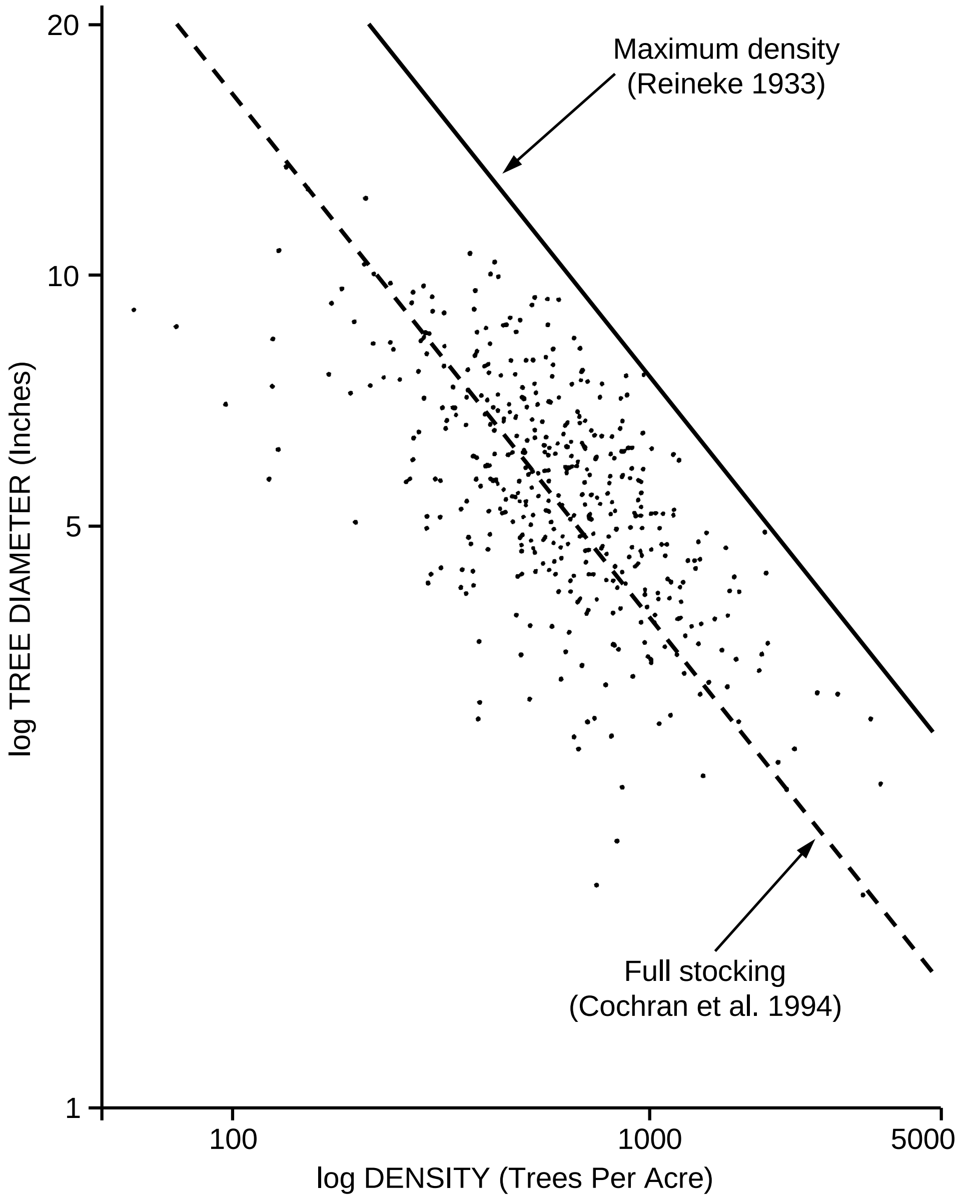

Figure 3 – Relationship between maximum density and full stocking. L.H. Reineke, creator of stand density index, plotted tree diameter and density for well-stocked, even-aged stands of a particular tree species on logarithmic scales (Reineke 1933). The result was a scatter plot where each dot represents one stand's data for mean diameter and trees per acre. Instead of following regular statistical methods (minimizing squared deviations), Reineke drew a straight line above the cloud of points (not through them). When a "least-squares" regression line was fitted to the scatter plot data, the result was average density for fully stocked stands. This average line is referred to as normal density or full stocking (Meyer 1961, McArdle et al. 1961). Cochran et al. (1994) use full stocking as a relative density reference level, so their upper and lower limits of a management zone are referenced to full stocking (fig. 2). The Cochran et al. (1994) process differs from Reineke's approach because Reineke used maximum density as a relative density reference level.

Table 1: Tree density, expressed using the “stand density index” metric, for four stocking thresholds and three potential vegetation groups.

Potential Vegetation Groups[2]	Tree Species	TREE DENSITY (SDI[1]) LLMZ	ULMZ	FS	Max[3]
Dry Upland Forest	Ponderosa pine	57	85	201	251
	Interior Douglas-fir	127	191	254	318
	Western larch	121	181	241	301
	Lodgepole pine	114	170	277	346
	Engelmann spruce Grand fir Subalpine fir	213	319	425	532
	Mixed composition[4]	81	121	218	272
Moist Upland Forest	Ponderosa pine	115	172	296	370
	Interior Douglas-fir	148	223	297	372
	Western larch	171	256	342	428
	Lodgepole pine	114	170	267	334
	Engelmann spruce	185	278	371	463
	Grand fir	246	369	492	615
	Subalpine fir	158	238	317	396
	Mixed composition[4]	163	244	333	417
Cold Upland Forest	Ponderosa pine	63	93	159	199
	Interior Douglas-fir	158	237	317	396
	Western larch	167	250	334	418
	Lodgepole pine	113	169	250	313
	Engelmann spruce	172	257	343	429
	Grand fir	173	259	346	433
	Subalpine fir	184	276	367	459
	Mixed composition[4]	132	197	275	344

[1] SDI refers to stand density index; all SDI values pertain to an irregular stand structure except for lodgepole pine, which pertains to an even-aged structure. The values in this table also represent a “trees per acre” (TPA) stocking level, but only when the quadratic mean diameter is 10 inches; at any other QMD, these values do not represent a TPA stocking level.

[2] Potential vegetation groups are a mid-scale unit in the potential vegetation hierarchy (Powell et al. 2006).

[3] LLMZ is the lower limit of the management zone; ULMZ is the upper limit of the management zone; FS is full stocking; and Max is maximum density (see fig. 1).

[4] Mixed composition is a weighted average based on these species mixes:

Dry upland forest: 70% ponderosa pine, 20% Douglas-fir, and 10% grand fir.

Moist upland forest: 30% Douglas-fir, 20% western larch, 20% lodgepole pine, and 30% grand fir.

Cold upland forest: 10% Douglas-fir, 10% western larch, 50% lodgepole pine, 20% Engelmann spruce, and 10% subalpine fir.

Table 2: Tree density, expressed using the "basal area per acre" metric, for four stocking thresholds and three potential vegetation groups.

Potential Vegetation Groups[2]	Tree Species	TREE DENSITY (BAA[1]) LLMZ	ULMZ	FS	Max[3]
Dry Upland Forest	Ponderosa pine	31	46	110	137
	Interior Douglas-fir	69	104	139	173
	Western larch	66	99	131	164
	Lodgepole pine	62	93	151	189
	Engelmann spruce Grand fir Subalpine fir	116	174	232	290
	Mixed composition[4]	44	66	119	148
Moist Upland Forest	Ponderosa pine	63	94	162	202
	Interior Douglas-fir	81	122	162	203
	Western larch	93	140	187	233
	Lodgepole pine	62	93	146	182
	Engelmann spruce	101	151	202	252
	Grand fir	134	201	268	335
	Subalpine fir	86	130	173	216
	Mixed composition[4]	89	133	182	227
Cold Upland Forest	Ponderosa pine	34	51	87	108
	Interior Douglas-fir	86	129	173	216
	Western larch	91	137	182	228
	Lodgepole pine	62	92	137	171
	Engelmann spruce	94	140	187	234
	Grand fir	94	141	189	236
	Subalpine fir	100	151	201	251
	Mixed composition[4]	72	108	150	187

[1] BAA refers to basal area, in square feet per acre; all BAA values pertain to a quadratic mean diameter of 10 inches and an irregular stand structure except for lodgepole pine, which pertains to an even-aged structure.

Footnotes 2-4 are the same as for table 1.

Table 3: Tree density, expressed using the "canopy cover percentage" metric, for four stocking thresholds and three potential vegetation groups.

Potential Vegetation Groups[2]	Tree Species	TREE DENSITY (CC%[1]) LLMZ	ULMZ	FS	Max[3]
Dry Upland Forest	Ponderosa pine	34	41	59	63
	Interior Douglas-fir	67	74	78	82
	Western larch	56	63	68	72
	Lodgepole pine	55	62	71	75
	Engelmann spruce Grand fir Subalpine fir	80	87	93	97
	Mixed composition[4]	43	50	61	65
Moist Upland Forest	Ponderosa pine	49	57	67	72
	Interior Douglas-fir	70	76	81	85
	Western larch	62	69	74	78
	Lodgepole pine	55	62	70	74
	Engelmann spruce	76	83	88	92
	Grand fir	83	91	96	99
	Subalpine fir	73	80	85	89
	Mixed composition[4]	76	83	89	93
Cold Upland Forest	Ponderosa pine	38	46	55	60
	Interior Douglas-fir	71	78	82	86
	Western larch	62	69	74	78
	Lodgepole pine	55	62	69	73
	Engelmann spruce	75	82	87	91
	Grand fir	77	84	89	93
	Subalpine fir	76	83	88	92
	Mixed composition[4]	58	65	71	75

[1] CC% refers to canopy cover percentage (for trees only); all CC% values pertain to a quadratic mean diameter of 10 inches and an irregular stand structure except for lodgepole pine, which pertains to an even-aged structure.

Footnotes 2-4 are the same as for table 1.

Table 4: Database queries using "trees per acre" information to calculate a tree density rating for mid-scale assessments involving potential vegetation groups.

Potential Vegetation Groups[1]	Diameter Class Categories[2]	Size Class Codes[3]	TREE DENSITY (TPA[4]) Low	Moderate	High[5]
Dry Upland Forest	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 478	479-713	≥ 714
	Poles (7" QMD)	5 or 6	≤ 107	108-159	≥ 160
	Small+ (12" QMD)	> 6	≤ 41	42-60	≥ 61
Moist Upland Forest	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 1,372	1,373-2,057	≥ 2,058
	Poles (7" QMD)	5 or 6	≤ 317	318-474	≥ 475
	Small+ (12" QMD)	> 6	≤ 125	126-186	≥ 187
Cold Upland Forest	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 915	916-1,368	≥ 1,369
	Poles (7" QMD)	5 or 6	≤ 210	211-313	≥ 314
	Small+ (12" QMD)	> 6	≤ 82	83-122	≥ 123

[1] Potential vegetation groups are a mid-scale unit in the potential vegetation hierarchy (Powell et al. 2006). Tree species selected to represent each potential vegetation group are: dry upland forest: ponderosa pine; moist upland forest: western larch; and cold upland forest: lodgepole pine.

[2] Some vegetation databases contain an average size class code representing the entire polygon. If an average size class is available, then queries should use it rather than layer-based size classes.

[3] Size class codes are described in Powell (2004); the values in this table summarize stocking levels (TPA) for three size class categories established using quadratic mean tree diameter.

[4] TPA refers to trees per acre; all TPA values pertain to an irregular stand structure except for the Cold Upland Forest potential vegetation group, which pertains to an even-aged structure.

[5] Low tree density corresponds to the lower limit of the management zone stocking threshold; moderate refers to the management zone; high corresponds to the upper limit of the management zone.

Table 5: Database queries using "basal area per acre" information to calculate a tree density rating for mid-scale assessments involving potential vegetation groups.

Potential Vegetation Groups[1]	Diameter Class Categories[2]	Size Class Codes[3]	TREE DENSITY (BAA[4]) Low	Moderate	High[5]
Dry Upland Forest	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 23	24-34	≥ 35
	Poles (7" QMD)	5 or 6	≤ 29	30-42	≥ 43
	Small+ (12" QMD)	> 6	≤ 32	33-47	≥ 48
Moist Upland Forest	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 67	68-100	≥ 101
	Poles (7" QMD)	5 or 6	≤ 85	86-126	≥ 127
	Small+ (12" QMD)	> 6	≤ 98	99-146	≥ 147
Cold Upland Forest	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 45	46-66	≥ 67
	Poles (7" QMD)	5 or 6	≤ 56	57-83	≥ 84
	Small+ (12" QMD)	> 6	≤ 64	65-96	≥ 97

Footnotes 1-3 and 5 are the same as for table 4.

[4] BAA refers to basal area, in square feet per acre; BAA values pertain to an irregular structure except for Cold Upland Forest, which pertains to an even-aged structure.

Table 6: Database queries using "canopy cover" information to calculate a tree density rating for mid-scale assessments involving potential vegetation groups.

Potential Vegetation Groups[1]	Diameter Class Categories[2]	Size Class Codes[3]	TREE DENSITY (CC%[4])		
			Low	Moderate	High[5]
Dry Upland Forest	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 29%	30-36	≥ 37%
	Poles (7" QMD)	5 or 6	≤ 33%	34-39	≥ 40%
	Small+ (12" QMD)	> 6	≤ 35%	36-42	≥ 43%
Moist Upland Forest	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 56%	57-63	≥ 64%
	Poles (7" QMD)	5 or 6	≤ 60%	61-67	≥ 68%
	Small+ (12" QMD)	> 6	≤ 63%	64-69	≥ 70%
Cold Upland Forest	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 49%	50-56	≥ 57%
	Poles (7" QMD)	5 or 6	≤ 53%	54-59	≥ 60%
	Small+ (12" QMD)	> 6	≤ 56%	57-62	≥ 63%

Footnotes 1-3 and 5 are the same as for table 4.

[4] CC% refers to canopy cover (for trees only); all values pertain to an irregular stand structure except for Cold Upland Forest, which pertains to an even-aged structure.

Table 7: Tree density, expressed using the "stand density index" metric, for four stocking thresholds and ten plant association groups.

Plant Association Groups[2]	Tree Species	TREE DENSITY (SDI[1]) LLMZ	ULMZ	FS	Max[3]
Cold Moist Upland Forest	Ponderosa pine				
	Interior Douglas-fir				
	Western larch				
	Lodgepole pine				
	Engelmann spruce				
	Grand fir				
	Subalpine fir	195	293	390	488
Cold Dry Upland Forest	Ponderosa pine	63	93	159	199
	Interior Douglas-fir	158	237	317	396
	Western larch	167	250	334	418
	Lodgepole pine	114	170	277	346
	Engelmann spruce	172	257	343	429
	Grand fir	173	259	346	433
	Subalpine fir	172	259	344	430
Cool Dry Upland Forest	Ponderosa pine				
	Interior Douglas-fir				
	Western larch				
	Lodgepole pine	112	167	223	279
	Engelmann spruce				
	Grand fir				
	Subalpine fir				
Cool Wet Upland Forest	Ponderosa pine				
	Interior Douglas-fir	179	269	359	449
	Western larch	142	213	284	355
	Lodgepole pine				
	Engelmann spruce	170	255	340	424
	Grand fir	263	395	526	658
	Subalpine fir				
Cool Very Moist Upland Forest	Ponderosa pine				
	Interior Douglas-fir				
	Western larch	176	264	353	441
	Lodgepole pine				
	Engelmann spruce	201	302	402	503
	Grand fir	249	375	499	624
	Subalpine fir				

Table 7: Tree density, expressed using the "stand density index" metric, for four stocking thresholds and ten plant association groups.

Plant Association Groups[2]	Tree Species	TREE DENSITY (SDI[1]) LLMZ	ULMZ	FS	Max[3]
Cool Moist Upland Forest	Ponderosa pine	93	140	304	380
	Interior Douglas-fir	175	263	351	439
	Western larch	178	267	356	445
	Lodgepole pine	114	170	267	334
	Engelmann spruce	184	276	367	459
	Grand fir	238	357	476	595
	Subalpine fir	158	238	317	396
Warm Very Moist Upland Forest	Ponderosa pine				
	Interior Douglas-fir	114	171	228	285
	Western larch	165	248	331	414
	Lodgepole pine				
	Engelmann spruce	152	228	304	380
	Grand fir	217	325	433	541
	Subalpine fir				
Warm Moist Upland Forest	Ponderosa pine	137	204	287	359
	Interior Douglas-fir	126	189	252	314
	Western larch	193	290	386	483
	Lodgepole pine				
	Engelmann spruce	220	330	440	550
	Grand fir	263	395	526	658
	Subalpine fir				
Warm Dry Upland Forest	Ponderosa pine	83	124	247	309
	Interior Douglas-fir	127	191	254	318
	Western larch	121	181	241	301
	Lodgepole pine	114	170	277	346
	Engelmann spruce				
	Grand fir	213	319	425	532
	Subalpine fir				
Hot Dry Upland Forest	Ponderosa pine	31	46	155	193
	Interior Douglas-fir				
	Western larch				
	Lodgepole pine				
	Engelmann spruce				
	Grand fir				
	Subalpine fir				

[1] Same as for table 1.

[2] Plant association groups are a mid-scale unit in the potential vegetation hierarchy (Powell et al. 2007).

[3] Same as for table 1.

Table 8: Tree density, expressed using the "basal area per acre" metric, for four stocking thresholds and ten plant association groups.

Plant Association Groups[2]	Tree Species	TREE DENSITY (BAA[1]) LLMZ	ULMZ	FS	Max[3]
Cold Moist Upland Forest	Ponderosa pine				
	Interior Douglas-fir				
	Western larch				
	Lodgepole pine				
	Engelmann spruce				
	Grand fir				
	Subalpine fir	106	160	213	266
Cold Dry Upland Forest	Ponderosa pine	34	51	87	108
	Interior Douglas-fir	86	129	173	216
	Western larch	91	137	182	228
	Lodgepole pine	62	93	151	189
	Engelmann spruce	94	140	187	234
	Grand fir	94	141	189	236
	Subalpine fir	94	141	188	235
Cool Dry Upland Forest	Ponderosa pine				
	Interior Douglas-fir				
	Western larch				
	Lodgepole pine	61	91	122	152
	Engelmann spruce				
	Grand fir				
	Subalpine fir				
Cool Wet Upland Forest	Ponderosa pine				
	Interior Douglas-fir	98	147	196	245
	Western larch	77	116	155	194
	Lodgepole pine				
	Engelmann spruce	93	139	185	231
	Grand fir	143	215	287	359
	Subalpine fir				
Cool Very Moist Upland Forest	Ponderosa pine				
	Interior Douglas-fir				
	Western larch	96	144	192	240
	Lodgepole pine				
	Engelmann spruce	110	164	219	274
	Grand fir	136	204	272	340
	Subalpine fir				

Table 8: Tree density, expressed using the "basal area per acre" metric, for four stocking thresholds and ten plant association groups.

Plant Association Groups[2]	Tree Species	TREE DENSITY (BAA[1]) LLMZ	ULMZ	FS	Max[3]
Cool Moist Upland Forest	Ponderosa pine	51	76	166	207
	Interior Douglas-fir	96	144	192	239
	Western larch	97	146	194	243
	Lodgepole pine	62	93	146	182
	Engelmann spruce	100	150	200	250
	Grand fir	130	195	259	324
	Subalpine fir	86	130	173	216
Warm Very Moist Upland Forest	Ponderosa pine				
	Interior Douglas-fir	62	93	124	155
	Western larch	90	135	181	226
	Lodgepole pine				
	Engelmann spruce	83	124	166	207
	Grand fir	118	177	236	295
	Subalpine fir				
Warm Moist Upland Forest	Ponderosa pine	74	111	157	196
	Interior Douglas-fir	68	103	137	171
	Western larch	105	158	211	263
	Lodgepole pine				
	Engelmann spruce	120	180	240	300
	Grand fir	143	215	287	359
	Subalpine fir				
Warm Dry Upland Forest	Ponderosa pine	45	67	135	169
	Interior Douglas-fir	69	104	139	173
	Western larch	66	99	131	164
	Lodgepole pine	62	93	151	189
	Engelmann spruce				
	Grand fir	116	174	232	290
	Subalpine fir				
Hot Dry Upland Forest	Ponderosa pine	17	25	84	105
	Interior Douglas-fir				
	Western larch				
	Lodgepole pine				
	Engelmann spruce				
	Grand fir				
	Subalpine fir				

[1] BAA refers to basal area, in square feet per acre; all BAA values pertain to a quadratic mean diameter of 10 inches and an irregular stand structure except for lodgepole pine, which pertains to an even-aged structure.

Footnotes 2-3 are the same as for table 7.

Table 9: Tree density, expressed using the "canopy cover percentage" metric, for four stocking thresholds and ten plant association groups.

Plant Association Groups[2]	Tree Species	TREE DENSITY (CC%[1]) LLMZ	ULMZ	FS	Max[3]
Cold Moist Upland Forest	Ponderosa pine				
	Interior Douglas-fir				
	Western larch				
	Lodgepole pine				
	Engelmann spruce				
	Grand fir				
	Subalpine fir	77	84	89	93
Cold Dry Upland Forest	Ponderosa pine	38	46	55	60
	Interior Douglas-fir	71	78	82	86
	Western larch	62	69	74	78
	Lodgepole pine	55	62	71	75
	Engelmann spruce	75	82	87	91
	Grand fir	77	84	89	93
	Subalpine fir	75	82	87	91
Cool Dry Upland Forest	Ponderosa pine				
	Interior Douglas-fir				
	Western larch				
	Lodgepole pine	55	62	67	71
	Engelmann spruce				
	Grand fir				
	Subalpine fir				
Cool Wet Upland Forest	Ponderosa pine				
	Interior Douglas-fir	73	80	84	88
	Western larch	59	66	71	75
	Lodgepole pine				
	Engelmann spruce	74	82	87	90
	Grand fir	84	92	97	100
	Subalpine fir				
Cool Very Moist Upland Forest	Ponderosa pine				
	Interior Douglas-fir				
	Western larch	63	70	75	79
	Lodgepole pine				
	Engelmann spruce	78	85	90	94
	Grand fir	83	91	96	100
	Subalpine fir				

Table 9: Tree density, expressed using the "canopy cover percentage" metric, for four stocking thresholds and ten plant association groups.

Plant Association Groups[2]	Tree Species	TREE DENSITY (CC%[1]) LLMZ	ULMZ	FS	Max[3]
Cool Moist Upland Forest	Ponderosa pine	45	53	67	72
	Interior Douglas-fir	73	79	84	88
	Western larch	63	70	75	79
	Lodgepole pine	55	62	70	74
	Engelmann spruce	76	83	88	92
	Grand fir	82	90	95	99
	Subalpine fir	73	80	85	89
Warm Very Moist Upland Forest	Ponderosa pine				
	Interior Douglas-fir	66	72	77	81
	Western larch	62	69	74	78
	Lodgepole pine				
	Engelmann spruce	73	80	85	89
	Grand fir	81	88	93	97
	Subalpine fir				
Warm Moist Upland Forest	Ponderosa pine	52	60	66	71
	Interior Douglas-fir	67	74	79	82
	Western larch	64	72	77	81
	Lodgepole pine				
	Engelmann spruce	79	86	91	95
	Grand fir	84	92	97	100
	Subalpine fir				
Warm Dry Upland Forest	Ponderosa pine	42	50	63	67
	Interior Douglas-fir	67	74	78	82
	Western larch	56	63	68	72
	Lodgepole pine	55	62	71	75
	Engelmann spruce				
	Grand fir	80	87	93	97
	Subalpine fir				
Hot Dry Upland Forest	Ponderosa pine	25	32	55	59
	Interior Douglas-fir				
	Western larch				
	Lodgepole pine				
	Engelmann spruce				
	Grand fir				
	Subalpine fir				

[1] CC% refers to canopy cover percentage (for trees only); all CC% values pertain to a quadratic mean diameter of 10 inches and an irregular stand structure except for lodgepole pine, which pertains to an even-aged structure.

Footnotes 2-3 are the same as for table 7.

Table 10: Database queries using "trees per acre" information to calculate a tree density rating for mid-scale assessments involving plant association groups.

Plant Association Groups[1]	Diameter Class Categories[2]	Size Class Codes[3]	TREE DENSITY (TPA[4]) Low	Moderate	High[5]
Cold Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 1,566	1,567-2,347	≥ 2,348
	Poles (7" QMD)	5 or 6	≤ 361	362-541	≥ 542
	Small+ (12" QMD)	> 6	≤ 142	143-212	≥ 213
Cold Dry UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 925	926-1,379	≥ 1,380
	Poles (7" QMD)	5 or 6	≤ 212	213-315	≥ 316
	Small+ (12" QMD)	> 6	≤ 83	84-123	≥ 124
Cool Dry UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 905	906-1,357	≥ 1,358
	Poles (7" QMD)	5 or 6	≤ 207	208-310	≥ 311
	Small+ (12" QMD)	> 6	≤ 81	82-121	≥ 122
Cool Wet UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 1,142	1,143-1,712	≥ 1,713
	Poles (7" QMD)	5 or 6	≤ 264	265-394	≥ 395
	Small+ (12" QMD)	> 6	≤ 104	105-155	≥ 156
Cool Very Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 1,414	1,415-2,120	≥ 2,121
	Poles (7" QMD)	5 or 6	≤ 327	328-489	≥ 490
	Small+ (12" QMD)	> 6	≤ 129	130-192	≥ 193
Cool Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 1,428	1,429-2,142	≥ 2,143
	Poles (7" QMD)	5 or 6	≤ 330	331-494	≥ 495
	Small+ (12" QMD)	> 6	≤ 130	131-194	≥ 195
Warm Very Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 701	702-1,050	≥ 1,051
	Poles (7" QMD)	5 or 6	≤ 195	196-291	≥ 292
	Small+ (12" QMD)	> 6	≤ 86	87-129	≥ 130
Warm Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 1,151	1,152-1,717	≥ 1,718
	Poles (7" QMD)	5 or 6	≤ 257	258-383	≥ 384
	Small+ (12" QMD)	> 6	≤ 99	100-147	≥ 148
Warm Dry UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 697	698-1,039	≥ 1,040
	Poles (7" QMD)	5 or 6	≤ 156	157-231	≥ 232
	Small+ (12" QMD)	> 6	≤ 60	61-88	≥ 89
Hot Dry UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 260	261-387	≥ 388
	Poles (7" QMD)	5 or 6	≤ 58	59-86	≥ 87
	Small+ (12" QMD)	> 6	≤ 22	23-32	≥ 33

[1] Plant association groups are a mid-scale unit in the potential vegetation hierarchy (Powell et al. 2006). "UF" refers to upland forest. Tree species selected to represent each plant association group are: cold moist UF: subalpine fir; cold dry UF: lodgepole pine; cool dry UF: lodgepole pine; cool wet UF: western larch; cool very moist UF: western larch; cool moist UF: western larch; warm very moist UF: interior Douglas-fir; warm moist UF: ponderosa pine; warm dry UF: ponderosa pine; hot dry UF: ponderosa pine.

Footnotes 2-3 and 5 are the same as for table 4.

[4] TPA refers to trees per acre; all TPA values pertain to an irregular stand structure except for the Cold Dry UF and Cool Dry UF plant association groups, which pertain to an even-aged structure.

Table 11: Database queries using “basal area per acre” information to calculate a tree density rating for mid-scale assessments involving plant association groups.

Plant Association Groups[1]	Diameter Class Categories[2]	Size Class Codes[3]	TREE DENSITY (BAA[4]) Low	Moderate	High[5]
Cold Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 77	78-114	≥ 115
	Poles (7" QMD)	5 or 6	≤ 96	97-144	≥ 145
	Small+ (12" QMD)	> 6	≤ 112	113-166	≥ 167
Cold Dry UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 45	46-67	≥ 68
	Poles (7" QMD)	5 or 6	≤ 57	58-83	≥ 84
	Small+ (12" QMD)	> 6	≤ 65	66-96	≥ 97
Cool Dry UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 44	45-66	≥ 67
	Poles (7" QMD)	5 or 6	≤ 55	56-82	≥ 83
	Small+ (12" QMD)	> 6	≤ 64	65-95	≥ 96
Cool Wet UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 56	57-83	≥ 84
	Poles (7" QMD)	5 or 6	≤ 71	72-105	≥ 106
	Small+ (12" QMD)	> 6	≤ 82	83-122	≥ 123
Cool Very Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 69	70-103	≥ 104
	Poles (7" QMD)	5 or 6	≤ 87	88-130	≥ 131
	Small+ (12" QMD)	> 6	≤ 101	102-150	≥ 151
Cool Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 70	71-104	≥ 105
	Poles (7" QMD)	5 or 6	≤ 88	89-131	≥ 132
	Small+ (12" QMD)	> 6	≤ 102	103-152	≥ 153
Warm Very Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 34	35-51	≥ 52
	Poles (7" QMD)	5 or 6	≤ 52	53-77	≥ 78
	Small+ (12" QMD)	> 6	≤ 68	69-101	≥ 102
Warm Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 56	57-83	≥ 84
	Poles (7" QMD)	5 or 6	≤ 69	70-101	≥ 102
	Small+ (12" QMD)	> 6	≤ 78	79-115	≥ 116
Warm Dry UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 34	35-50	≥ 51
	Poles (7" QMD)	5 or 6	≤ 42	43-61	≥ 62
	Small+ (12" QMD)	> 6	≤ 47	48-69	≥ 70
Hot Dry UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 13	14-18	≥ 19
	Poles (7" QMD)	5 or 6	≤ 15	16-22	≥ 23
	Small+ (12" QMD)	> 6	≤ 17	18-25	≥ 26

Footnotes 1-3 and 5 are the same as for table 10.

[4] BAA refers to basal area in square feet per acre; all BAA values pertain to an irregular stand structure except for the Cold Dry UF and Cool Dry UF plant association groups, which pertain to an even-aged structure.

Table 12: Database queries using "canopy cover percentage" information to calculate a tree density rating for mid-scale assessments involving plant association groups.

Plant Association Groups[1]	Diameter Class Categories[2]	Size Class Codes[3]	TREE DENSITY (CC%[4]) Low	Moderate	High[5]
Cold Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 72%	73-78	≥ 79%
	Poles (7" QMD)	5 or 6	≤ 75%	76-82	≥ 83%
	Small+ (12" QMD)	> 6	≤ 78%	79-84	≥ 85%
Cold Dry UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 49%	50-56	≥ 57%
	Poles (7" QMD)	5 or 6	≤ 53%	54-59	≥ 60%
	Small+ (12" QMD)	> 6	≤ 56%	57-62	≥ 63%
Cool Dry UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 49%	50-55	≥ 56%
	Poles (7" QMD)	5 or 6	≤ 53%	54-59	≥ 60%
	Small+ (12" QMD)	> 6	≤ 55%	56-62	≥ 63%
Cool Wet UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 53%	54-59	≥ 60%
	Poles (7" QMD)	5 or 6	≤ 57%	58-63	≥ 64%
	Small+ (12" QMD)	> 6	≤ 60%	61-66	≥ 67%
Cool Very Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 57%	58-63	≥ 64%
	Poles (7" QMD)	5 or 6	≤ 61%	62-67	≥ 68%
	Small+ (12" QMD)	> 6	≤ 64%	65-70	≥ 71%
Cool Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 57%	58-63	≥ 64%
	Poles (7" QMD)	5 or 6	≤ 61%	62-68	≥ 69%
	Small+ (12" QMD)	> 6	≤ 64%	65-70	≥ 71%
Warm Very Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 57%	58-62	≥ 63%
	Poles (7" QMD)	5 or 6	≤ 63%	64-69	≥ 70%
	Small+ (12" QMD)	> 6	≤ 67%	68-73	≥ 74%
Warm Moist UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 48%	49-54	≥ 55%
	Poles (7" QMD)	5 or 6	≤ 51%	52-58	≥ 59%
	Small+ (12" QMD)	> 6	≤ 53%	54-60	≥ 61%
Warm Dry UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 38%	39-45	≥ 46%
	Poles (7" QMD)	5 or 6	≤ 42%	43-48	≥ 49%
	Small+ (12" QMD)	> 6	≤ 44%	45-51	≥ 52%
Hot Dry UF	Seed-Sap (3" QMD)	≥ 1, < 5	≤ 21%	22-27	≥ 28%
	Poles (7" QMD)	5 or 6	≤ 24%	25-30	≥ 31%
	Small+ (12" QMD)	> 6	≤ 26%	27-32	≥ 33%

Footnotes 1-3 and 5 are the same as for table 10.

[4] CC% refers to canopy cover percentage (for trees only); all CC% values pertain to an irregular stand structure except for the Cold Dry UF and Cool Dry UF plant association groups, which pertain to an even-aged structure.

Table 13: Suggested stocking levels, summarized by plant association group, for upland forest sites.

Plant Association Groups[1]	Tree Species[2]	Diameter Class Categories[3]	Diameter Class Midpoint[4]	LOWER LIMIT OF THE MANAGEMENT ZONE[5]				UPPER LIMIT OF THE MANAGEMENT ZONE[5]			
				SDI	TPA	BAA	CC%	SDI	TPA	BAA	CC%
Cold Moist UF	**ABLA**	Seed-Sap (< 5")	3" QMD	195	1,566	77	72	293	2,348	115	79
		Poles (5-9")	7" QMD	195	361	96	75	293	542	145	83
		Small+ (> 9")	12" QMD	195	142	112	78	293	213	167	85
Cold Dry UF	**PIPO**	Seed-Sap (< 5")	3" QMD	63	527	26	33	93	787	39	41
		Poles (5-9")	7" QMD	63	118	32	37	93	176	47	44
		Small+ (> 9")	12" QMD	63	45	35	39	93	68	53	46
	PSME	Seed-Sap (< 5")	3" QMD	158	975	48	62	237	1,463	72	68
		Poles (5-9")	7" QMD	158	271	73	68	237	407	109	75
		Small+ (> 9")	12" QMD	158	120	94	73	237	180	142	79
	LAOC	Seed-Sap (< 5")	3" QMD	167	1,340	66	56	250	2,011	99	63
		Poles (5-9")	7" QMD	167	310	83	60	250	464	124	67
		Small+ (> 9")	12" QMD	167	122	96	63	250	183	144	70
	PICO	Seed-Sap (< 5")	3" QMD	114	925	45	49	170	1,380	68	57
		Poles (5-9")	7" QMD	114	212	57	53	170	316	84	60
		Small+ (> 9")	12" QMD	114	83	65	56	170	124	97	63
	PIEN	Seed-Sap (< 5")	3" QMD	172	1,377	68	69	257	2,066	101	76
		Poles (5-9")	7" QMD	172	318	85	73	257	477	127	80
		Small+ (> 9")	12" QMD	172	125	98	76	257	188	148	83
	ABGR	Seed-Sap (< 5")	3" QMD	173	1,389	68	71	259	2,083	102	78
		Poles (5-9")	7" QMD	173	321	86	75	259	481	129	82
		Small+ (> 9")	12" QMD	173	126	99	78	259	189	148	85

Plant Association Groups[1]	Tree Species[2]	Diameter Class Categories[3]	Diameter Class Midpoint[4]	LOWER LIMIT OF THE MANAGEMENT ZONE[5] SDI	TPA	BAA	CC%	UPPER LIMIT OF THE MANAGEMENT ZONE[5] SDI	TPA	BAA	CC%
Cold Dry UF (cont.)	**ABLA**	Seed-Sap (< 5")	3" QMD	172	1,383	68	69	259	2,073	102	76
		Poles (5-9")	7" QMD	172	319	85	73	259	479	128	80
		Small+ (> 9")	12" QMD	172	126	99	76	259	188	148	83
Cool Dry UF	**PICO**	Seed-Sap (< 5")	3" QMD	112	905	44	49	167	1,358	67	56
		Poles (5-9")	7" QMD	112	207	55	53	167	311	83	60
		Small+ (> 9")	12" QMD	112	81	64	55	167	122	96	63
Cool Wet UF	**PSME**	Seed-Sap (< 5")	3" QMD	179	1,105	54	64	269	1,658	81	70
		Poles (5-9")	7" QMD	179	307	82	70	269	461	123	77
		Small+ (> 9")	12" QMD	179	136	107	75	269	204	160	81
	LAOC	Seed-Sap (< 5")	3" QMD	142	1,142	56	53	213	1,713	84	60
		Poles (5-9")	7" QMD	142	264	71	57	213	395	106	64
		Small+ (> 9")	12" QMD	142	104	82	60	213	156	123	67
	PIEN	Seed-Sap (< 5")	3" QMD	170	1,364	67	69	255	2,047	100	76
		Poles (5-9")	7" QMD	170	315	84	73	255	473	126	80
		Small+ (> 9")	12" QMD	170	124	97	76	255	186	146	83
	ABGR	Seed-Sap (< 5")	3" QMD	263	2,113	104	78	395	3,170	156	86
		Poles (5-9")	7" QMD	263	488	130	83	395	732	196	90
		Small+ (> 9")	12" QMD	263	192	151	85	395	288	226	92
Cool Very Moist UF	**LAOC**	Seed-Sap (< 5")	3" QMD	176	1,414	69	57	264	2,121	104	64
		Poles (5-9")	7" QMD	176	327	87	61	264	490	131	68
		Small+ (> 9")	12" QMD	176	129	101	64	264	193	151	71

Plant Association Groups[1]	Tree Species[2]	Diameter Class Categories[3]	Diameter Class Midpoint[4]	LOWER LIMIT OF THE MANAGEMENT ZONE[5] SDI	TPA	BAA	CC%	UPPER LIMIT OF THE MANAGEMENT ZONE[5] SDI	TPA	BAA	CC%
Cool Very Moist UF (cont.)	**PIEN**	Seed-Sap (< 5")	3" QMD	201	1,613	79	72	302	2,419	119	79
		Poles (5-9")	7" QMD	201	373	100	76	302	559	149	83
		Small+ (> 9")	12" QMD	201	147	115	79	302	220	173	86
	ABGR	Seed-Sap (< 5")	3" QMD	249	2,004	98	78	375	3,006	148	85
		Poles (5-9")	7" QMD	249	463	124	82	375	694	185	89
		Small+ (> 9")	12" QMD	249	182	143	84	375	273	214	91
Cool Moist UF	**PIPO**	Seed-Sap (< 5")	3" QMD	93	786	39	41	140	1,173	58	48
		Poles (5-9")	7" QMD	93	176	47	44	140	262	70	51
		Small+ (> 9")	12" QMD	93	68	53	46	140	101	79	54
	PSME	Seed-Sap (< 5")	3" QMD	175	1,081	53	63	263	1,622	80	70
		Poles (5-9")	7" QMD	175	301	80	70	263	451	121	77
		Small+ (> 9")	12" QMD	175	133	104	74	263	200	157	81
	LAOC	Seed-Sap (< 5")	3" QMD	178	1,428	70	57	267	2,143	105	64
		Poles (5-9")	7" QMD	178	330	88	61	267	495	132	69
		Small+ (> 9")	12" QMD	178	130	102	64	267	195	153	71
	PICO	Seed-Sap (< 5")	3" QMD	114	925	45	49	170	1,380	68	57
		Poles (5-9")	7" QMD	114	212	57	53	170	316	84	60
		Small+ (> 9")	12" QMD	114	83	65	56	170	124	97	63
	PIEN	Seed-Sap (< 5")	3" QMD	184	1,473	72	70	276	2,210	108	78
		Poles (5-9")	7" QMD	184	340	91	74	276	510	136	81
		Small+ (> 9")	12" QMD	184	134	105	77	276	201	158	84

Plant Association Groups[1]	Tree Species[2]	Diameter Class Categories[3]	Diameter Class Midpoint[4]	LOWER LIMIT OF THE MANAGEMENT ZONE[5] SDI	TPA	BAA	CC%	UPPER LIMIT OF THE MANAGEMENT ZONE[5] SDI	TPA	BAA	CC%
Cool Moist UF (cont.)	**ABGR**	Seed-Sap (< 5")	3" QMD	238	1,910	94	77	357	2,866	141	84
		Poles (5-9")	7" QMD	238	441	118	81	357	662	177	88
		Small+ (> 9")	12" QMD	238	174	136	83	357	260	204	91
	ABLA	Seed-Sap (< 5")	3" QMD	158	1,273	62	68	238	1,909	94	75
		Poles (5-9")	7" QMD	158	294	78	72	238	441	118	79
		Small+ (> 9")	12" QMD	158	116	91	74	238	173	136	81
Warm Very Moist UF	**PSME**	Seed-Sap (< 5")	3" QMD	114	701	34	57	171	1,051	52	63
		Poles (5-9")	7" QMD	114	195	52	63	171	292	78	70
		Small+ (> 9")	12" QMD	114	86	68	67	171	130	102	74
	LAOC	Seed-Sap (< 5")	3" QMD	165	1,327	65	56	248	1,990	98	63
		Poles (5-9")	7" QMD	165	306	82	60	248	460	123	67
		Small+ (> 9")	12" QMD	165	121	95	63	248	181	142	70
	PIEN	Seed-Sap (< 5")	3" QMD	152	1,219	60	67	228	1,829	90	74
		Poles (5-9")	7" QMD	152	282	75	71	228	422	113	78
		Small+ (> 9")	12" QMD	152	111	87	74	228	166	130	81
	ABGR	Seed-Sap (< 5")	3" QMD	217	1,740	85	75	325	2,609	128	82
		Poles (5-9")	7" QMD	217	402	107	79	325	602	161	86
		Small+ (> 9")	12" QMD	217	158	124	82	325	237	186	89
Warm Moist UF	**PIPO**	Seed-Sap (< 5")	3" QMD	137	1,151	56	48	204	1,718	84	55
		Poles (5-9")	7" QMD	137	257	69	51	204	384	102	59
		Small+ (> 9")	12" QMD	137	99	78	53	204	148	116	61

Plant Association Groups[1]	Tree Species[2]	Diameter Class Categories[3]	Diameter Class Midpoint[4]	LOWER LIMIT OF THE MANAGEMENT ZONE[5] SDI	TPA	BAA	CC%	UPPER LIMIT OF THE MANAGEMENT ZONE[5] SDI	TPA	BAA	CC%
Warm Moist UF (cont.)	PSME	Seed-Sap (< 5")	3" QMD	126	774	38	58	189	1,160	57	65
		Poles (5-9")	7" QMD	126	215	57	65	189	323	86	71
		Small+ (> 9")	12" QMD	126	95	75	69	189	143	112	75
	LAOC	Seed-Sap (< 5")	3" QMD	193	1,550	76	59	290	2,325	114	66
		Poles (5-9")	7" QMD	193	358	96	63	290	537	144	70
		Small+ (> 9")	12" QMD	193	141	111	65	290	211	166	73
	PIEN	Seed-Sap (< 5")	3" QMD	220	1,765	87	74	330	2,648	130	81
		Poles (5-9")	7" QMD	220	408	109	78	330	611	163	85
		Small+ (> 9")	12" QMD	220	160	126	80	330	241	189	87
	ABGR	Seed-Sap (< 5")	3" QMD	263	2,113	104	78	395	3,170	156	86
		Poles (5-9")	7" QMD	263	488	130	83	395	732	196	90
		Small+ (> 9")	12" QMD	263	192	151	85	395	288	226	92
Warm Dry UF	PIPO	Seed-Sap (< 5")	3" QMD	83	697	34	38	124	1,040	51	46
		Poles (5-9")	7" QMD	83	156	42	42	124	232	62	49
		Small+ (> 9")	12" QMD	83	60	47	44	124	89	70	52
	PSME	Seed-Sap (< 5")	3" QMD	127	784	38	58	191	1,176	58	65
		Poles (5-9")	7" QMD	127	218	58	65	191	327	87	71
		Small+ (> 9")	12" QMD	127	97	76	69	191	145	114	76
	LAOC	Seed-Sap (< 5")	3" QMD	121	968	48	50	181	1,452	71	57
		Poles (5-9")	7" QMD	121	223	60	54	181	335	90	62
		Small+ (> 9")	12" QMD	121	88	69	57	181	132	104	64

Plant Association Groups[1]	Tree Species[2]	Diameter Class Categories[3]	Diameter Class Midpoint[4]	LOWER LIMIT OF THE MANAGEMENT ZONE[5]				UPPER LIMIT OF THE MANAGEMENT ZONE[5]			
				SDI	TPA	BAA	CC%	SDI	TPA	BAA	CC%
Warm Dry UF (cont.)	**PICO**	Seed-Sap (< 5")	3" QMD	114	925	45	49	170	1,380	68	57
		Poles (5-9")	7" QMD	114	212	57	53	170	316	84	60
		Small+ (> 9")	12" QMD	114	83	65	56	170	124	97	63
	ABGR	Seed-Sap (< 5")	3" QMD	213	1,708	84	75	319	2,562	126	82
		Poles (5-9")	7" QMD	213	394	105	79	319	592	158	86
		Small+ (> 9")	12" QMD	213	155	122	81	319	233	183	89
Hot Dry UF	**PIPO**	Seed-Sap (< 5")	3" QMD	31	260	13	21	46	388	19	28
		Poles (5-9")	7" QMD	31	58	15	24	46	87	23	31
		Small+ (> 9")	12" QMD	31	22	17	26	46	33	26	33

Sources: Based on Powell (1999).

[1] Plant association groups are a mid-scale unit in the potential vegetation hierarchy (Powell et al. 2006). "UF" refers to upland forest.

[2] Tree species acronyms are: ABGR: grand fir; ABLA: subalpine fir; LAOC: western larch; PICO: lodgepole pine; PIEN: Engelmann spruce; PIPO: ponderosa pine; PSME: interior Douglas-fir.

[3] Some vegetation databases contain an average size class code representing the entire polygon; the values in this table summarize stocking levels (SDI, TPA, BAA, CC%) for three size class categories (based on tree diameter).

[4] QMD is quadratic mean diameter at breast height, a measurement point assumed to be 4½ feet above the average ground level.

[5] SDI refers to stand density index; TPA refers to trees per acre; BAA refers to basal area per acre; CC% refers to canopy cover percentage (for trees only); all values in this table (SDI, TPA, BAA, CC%) pertain to an irregular stand structure except for lodgepole pine, which pertains to an even-aged structure.

Table 14: Suggested stocking levels, summarized by potential vegetation group, for upland forest sites.

Potential Vegetation Groups[1]	Tree Species[2]	Diameter Class Categories[3]	Diameter Class Midpoint[4]	LOWER LIMIT OF THE MANAGEMENT ZONE[5]				UPPER LIMIT OF THE MANAGEMENT ZONE[5]			
				SDI	TPA	BAA	CC%	SDI	TPA	BAA	CC%
Cold Upland Forest	PIPO	Seed-Sap (< 5")	3" QMD	63	527	26	33	93	787	39	41
		Poles (5-9")	7" QMD	63	118	32	37	93	176	47	44
		Small+ (> 9")	12" QMD	63	45	35	39	93	68	53	46
	PSME	Seed-Sap (< 5")	3" QMD	158	975	48	62	237	1,463	72	68
		Poles (5-9")	7" QMD	158	271	73	68	237	407	109	75
		Small+ (> 9")	12" QMD	158	120	94	73	237	180	142	79
	LAOC	Seed-Sap (< 5")	3" QMD	167	1,340	66	56	250	2,011	99	63
		Poles (5-9")	7" QMD	167	310	83	60	250	464	124	67
		Small+ (> 9")	12" QMD	167	122	96	63	250	183	144	70
	PICO	Seed-Sap (< 5")	3" QMD	113	915	45	49	169	1,369	67	57
		Poles (5-9")	7" QMD	113	210	56	53	169	314	84	60
		Small+ (> 9")	12" QMD	113	82	64	56	169	123	97	63
	PIEN	Seed-Sap (< 5")	3" QMD	172	1,377	68	69	257	2,066	101	76
		Poles (5-9")	7" QMD	172	318	85	73	257	477	127	80
		Small+ (> 9")	12" QMD	172	125	98	76	257	188	148	83
	ABGR	Seed-Sap (< 5")	3" QMD	173	1,389	68	71	259	2,083	102	78
		Poles (5-9")	7" QMD	173	321	86	75	259	481	129	82
		Small+ (> 9")	12" QMD	173	126	99	78	259	189	148	85
	ABLA	Seed-Sap (< 5")	3" QMD	184	1,474	72	70	276	2,211	109	77
		Poles (5-9")	7" QMD	184	340	91	74	276	511	136	82
		Small+ (> 9")	12" QMD	184	134	105	77	276	201	158	84

Potential Vegetation Groups[1]	Tree Species[2]	Diameter Class Categories[3]	Diameter Class Midpoint[4]	LOWER LIMIT OF THE MANAGEMENT ZONE[5]				UPPER LIMIT OF THE MANAGEMENT ZONE[5]			
				SDI	TPA	BAA	CC%	SDI	TPA	BAA	CC%
Moist Upland Forest	PIPO	Seed-Sap (< 5")	3" QMD	115	969	48	44	172	1,445	71	51
		Poles (5-9")	7" QMD	115	216	58	48	172	323	86	55
		Small+ (> 9")	12" QMD	115	83	65	50	172	125	98	58
	PSME	Seed-Sap (< 5")	3" QMD	148	915	45	60	223	1,373	67	67
		Poles (5-9")	7" QMD	148	254	68	67	223	382	102	74
		Small+ (> 9")	12" QMD	148	113	88	71	223	169	133	78
	LAOC	Seed-Sap (< 5")	3" QMD	171	1,372	67	56	256	2,058	101	64
		Poles (5-9")	7" QMD	171	317	85	60	256	475	127	68
		Small+ (> 9")	12" QMD	171	125	98	63	256	187	147	70
	PICO	Seed-Sap (< 5")	3" QMD	114	925	45	49	170	1,380	68	57
		Poles (5-9")	7" QMD	114	212	57	53	170	316	84	60
		Small+ (> 9")	12" QMD	114	83	65	56	170	124	97	63
	PIEN	Seed-Sap (< 5")	3" QMD	185	1,487	73	70	278	2,231	109	78
		Poles (5-9")	7" QMD	185	344	92	74	278	515	138	81
		Small+ (> 9")	12" QMD	185	135	106	77	278	203	159	84
	ABGR	Seed-Sap (< 5")	3" QMD	246	1,976	97	77	369	2,964	145	84
		Poles (5-9")	7" QMD	246	456	122	82	369	684	183	89
		Small+ (> 9")	12" QMD	246	180	141	84	369	269	211	91
	ABLA	Seed-Sap (< 5")	3" QMD	158	1,273	62	68	238	1,909	94	75
		Poles (5-9")	7" QMD	158	294	78	72	238	441	118	79
		Small+ (> 9")	12" QMD	158	116	91	74	238	173	136	81

Potential Vegetation Groups[1]	Tree Species[2]	Diameter Class Categories[3]	Diameter Class Midpoint[4]	LOWER LIMIT OF THE MANAGEMENT ZONE[5] SDI	TPA	BAA	CC%	UPPER LIMIT OF THE MANAGEMENT ZONE[5] SDI	TPA	BAA	CC%
Dry Upland Forest	PIPO	Seed-Sap (< 5")	3" QMD	57	478	23	29	85	714	35	37
		Poles (5-9")	7" QMD	57	107	29	33	85	160	43	40
		Small+ (> 9")	12" QMD	57	41	32	35	85	61	48	43
	PSME	Seed-Sap (< 5")	3" QMD	127	784	38	58	191	1,176	58	65
		Poles (5-9")	7" QMD	127	218	58	65	191	327	87	71
		Small+ (> 9")	12" QMD	127	97	76	69	191	145	114	76
	LAOC	Seed-Sap (< 5")	3" QMD	121	968	48	50	181	1,452	71	57
		Poles (5-9")	7" QMD	121	223	60	54	181	335	90	62
		Small+ (> 9")	12" QMD	121	88	69	57	181	132	104	64
	PICO	Seed-Sap (< 5")	3" QMD	114	925	45	49	170	1,380	68	57
		Poles (5-9")	7" QMD	114	212	57	53	170	316	84	60
		Small+ (> 9")	12" QMD	114	83	65	56	170	124	97	63
	ABGR	Seed-Sap (< 5")	3" QMD	213	1,708	84	75	319	2,562	126	82
		Poles (5-9")	7" QMD	213	394	105	79	319	592	158	86
		Small+ (> 9")	12" QMD	213	155	122	81	319	233	183	89

Sources: Based on Powell (1999).

1 Potential vegetation groups are a mid-scale unit in the potential vegetation hierarchy (Powell et al. 2006).

2 Tree species acronyms are: ABGR: grand fir; ABLA: subalpine fir; LAOC: western larch; PICO: lodgepole pine; PIEN: Engelmann spruce; PIPO: ponderosa pine; PSME: interior Douglas-fir.

3 Some vegetation databases contain an average size class code representing the entire polygon; the values in this table summarize stocking levels (SDI, TPA, BAA, CC%) for three size class categories (based on tree diameter).

4 QMD is quadratic mean diameter at breast height, a measurement point assumed to be 4½ feet above the average ground level.

5 SDI refers to stand density index; TPA refers to trees per acre; BAA refers to basal area per acre; CC% refers to canopy cover percentage (for trees only); all table values (SDI, TPA, BAA, CC%) pertain to an irregular stand structure except for lodgepole pine, which pertains to an even-aged structure.

Table 15: Maximum stand density index values by tree species and plant association.

PLANT ASSOCIATION	ECOCLASS	PIPO	PSME	LAOC	PICO	PIEN	ABGR	ABLA2
ABLA2/TRCA3	CEF331				346	430		478
ABLA2/CLUN	CES131			513		586		520
ABLA2/LIBO2	CES414			513		474		419
ABLA2/MEFE	CES221							520
ABLA2/VAME	CES311			478	319	478		331
ABLA2/VASC	CES411		458	475	346	458		456
ABLA2/VASC/POPU	CES415		458	475	346	458		456
ABLA2/CAGE	CAG111				346			465
ABGR/GYDR	CWF611						691	
ABGR/POMU-ASCA3	CWF612			438		586	608	
ABGR/TRCA3	CWF512			498		485	693	
ABGR/ACGL	CWS912		301	439		405	576	
ABGR/TABR/CLUN	CWC811					533	700	
ABGR/TABR/LIBO2	CWC812		475	378		374	700	
ABGR/CLUN	CWF421		475	513	346	586	700	
ABGR/LIBO2	CWF311	456	475	463	346	499	645	466
ABGR/VAME	CWS211	365	475	513	298	426	569	515
ABGR/VASC-LIBO2	CWS812		434	316	346	436	618	230
ABGR/VASC	CWS811	215	343	380	346		460	
ABGR/SPBE	CWS321	319	248				443	
ABGR/CARU	CWG112	395	446	384	346		555	
ABGR/CAGE	CWG111	263	376				700	
ABGR/BRVU	CWG211			513		586	700	
PICO/CARU	CLS416				279			
PSME/ACGL-PHMA	CDS722	351	346					
PSME/PHMA	CDS711	343	281	320				
PSME/HODI	CDS611	425	319					
PSME/SPBE	CDS634	441	464					
PSME/SYAL	CDS622	341	309	256				
PSME/SYOR	CDS625	451						
PSME/VAME	CDS812	241	229					
PSME/CARU	CDG121	329	330					
PSME/CAGE	CDG111	278	351					
PIPO/SYAL	CPS522	398						
PIPO/SYOR	CPS525	325						
PIPO/CARU	CPG221	456						
PIPO/CAGE	CPG222	251						
PIPO/CELE/CAGE	CPS232	290						
PIPO/CELE/PONE	CPS233	199						
PIPO/CELE/FEID-AGSP	CPS234	196						
PIPO/PUTR/CAGE	CPS222	255						
PIPO/PUTR/CARO	CPS221	304						
PIPO/PUTR/FEID-AGSP	CPS226	231						
PIPO/ARTRV/FEID-AGSP	CPS131	238						
PIPO/FEID	CPG112	243						
PIPO/AGSP	CPG111	166						

Sources/Notes: The plant associations included here are those known to occur on upland sites of the Umatilla National Forest (see Powell 1999). Plant association acronyms (ABLA2/TRCA3) and ecoclass codes (CEF331) are used to record plant associations on field forms and in computer databases; they are described in Hall (1998, as supplemented). The maximum SDI values shown in each species column were calculated as 125% of full stocking (see table 3 in Powell 1999); full stocking values are provided by Cochran et al. (1994) and Powell (1999). The tree species acronyms used as column headings are described in footnotes to tables 13 and 14.

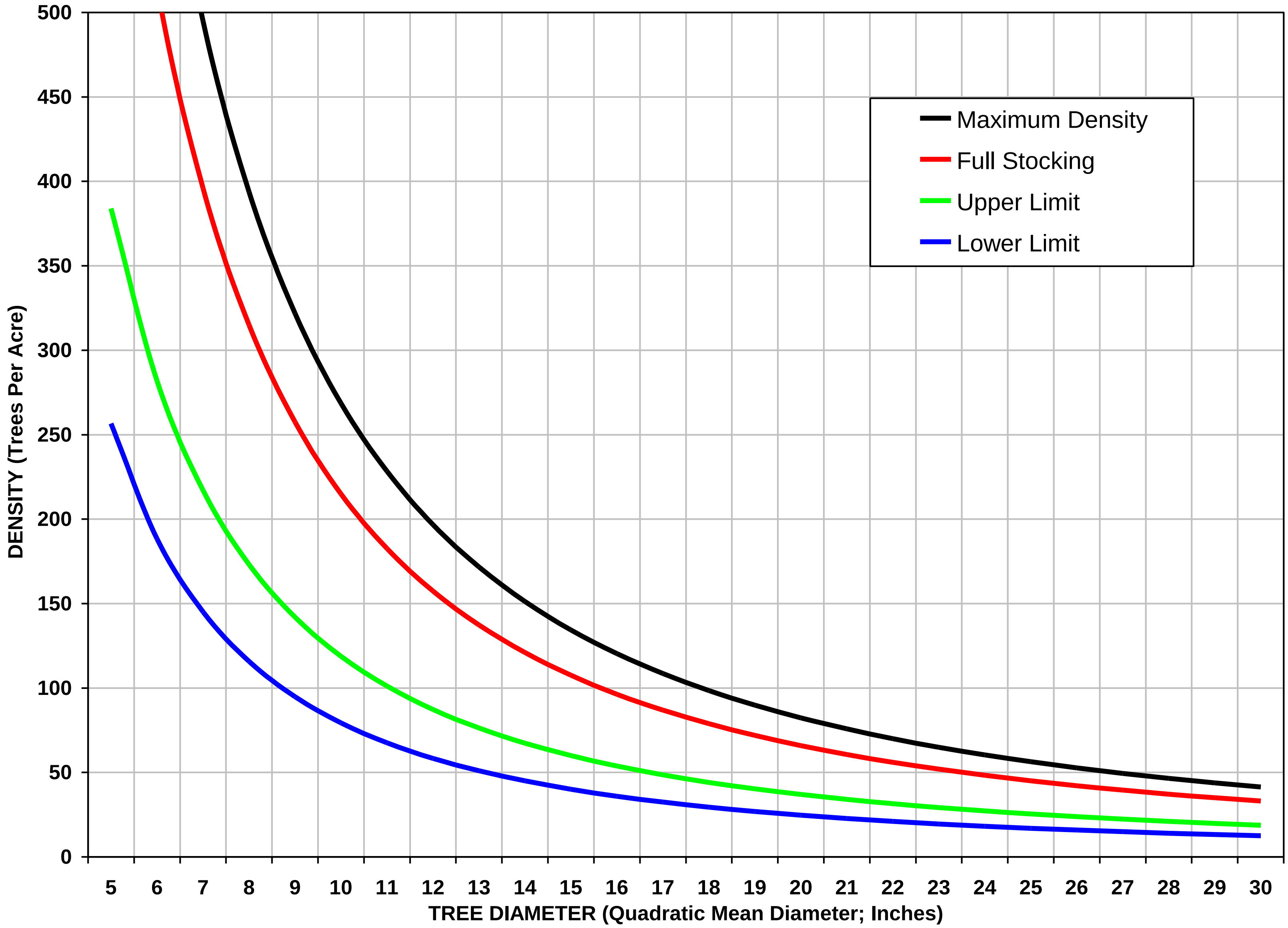

Figure 4 – Suggested stocking levels (trees per acre) for the dry upland forest PVG, and for a range of quadratic mean diameters, a mixed composition (70% ponderosa pine, 20% Douglas-fir, 10% grand fir), and an irregular stand structure.

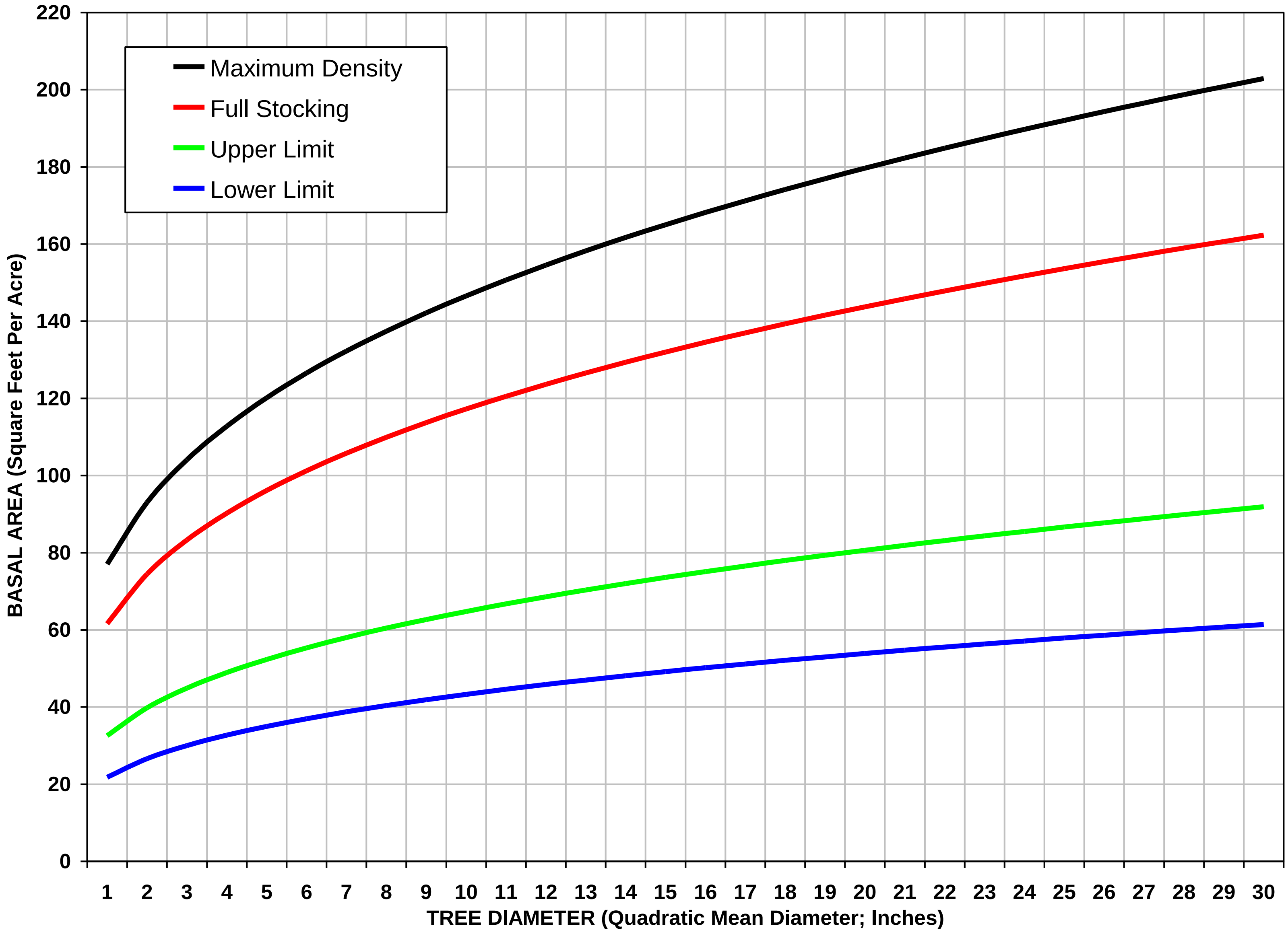

Figure 5 – Suggested stocking levels (basal area, ft^2/acre) for the dry upland forest PVG, and for a range of quadratic mean diameters, a mixed composition (70% ponderosa pine, 20% Douglas-fir, 10% grand fir), and an irregular stand structure.

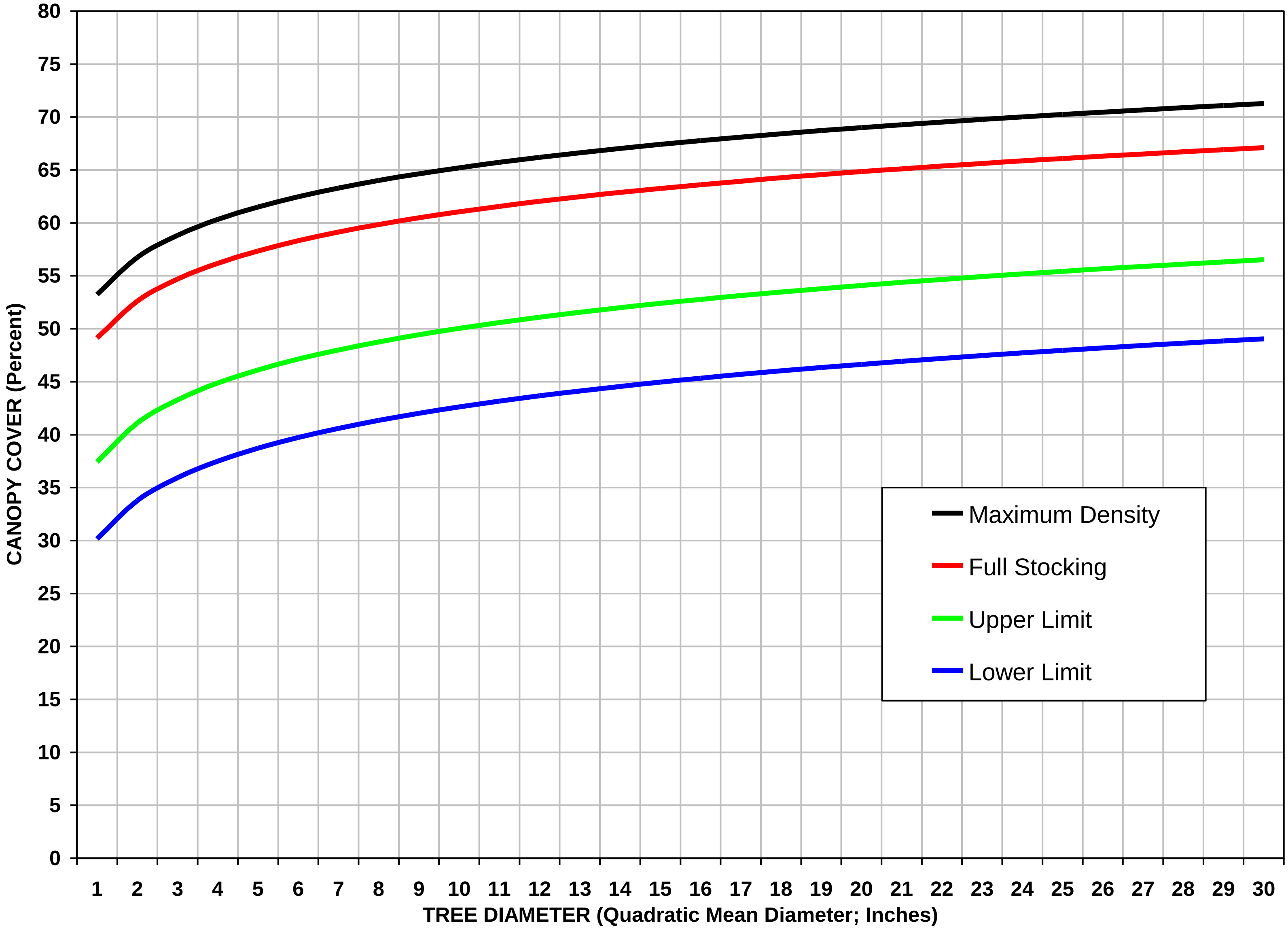

Figure 6 – Suggested stocking levels (canopy cover, percent) for the dry upland forest PVG, and for a range of quadratic mean diameters, a mixed composition (70% ponderosa pine, 20% Douglas-fir, 10% grand fir), and an irregular stand structure.

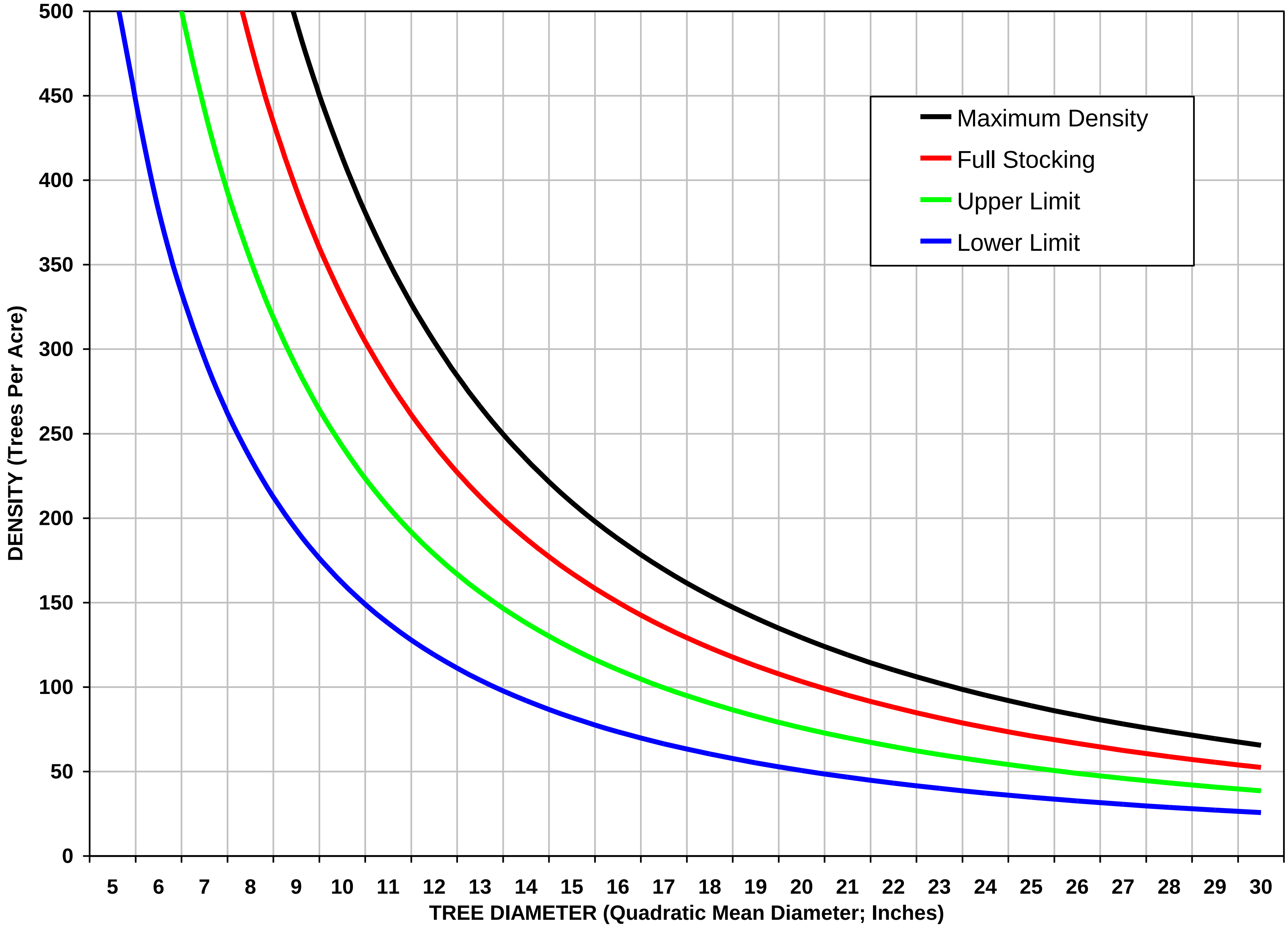

Figure 7 – Suggested stocking levels (trees per acre) for the moist upland forest PVG, and for a range of quadratic mean diameters, a mixed composition (30% Douglas-fir, 20% western larch, 20% lodgepole pine, 30% grand fir), and an irregular stand structure.

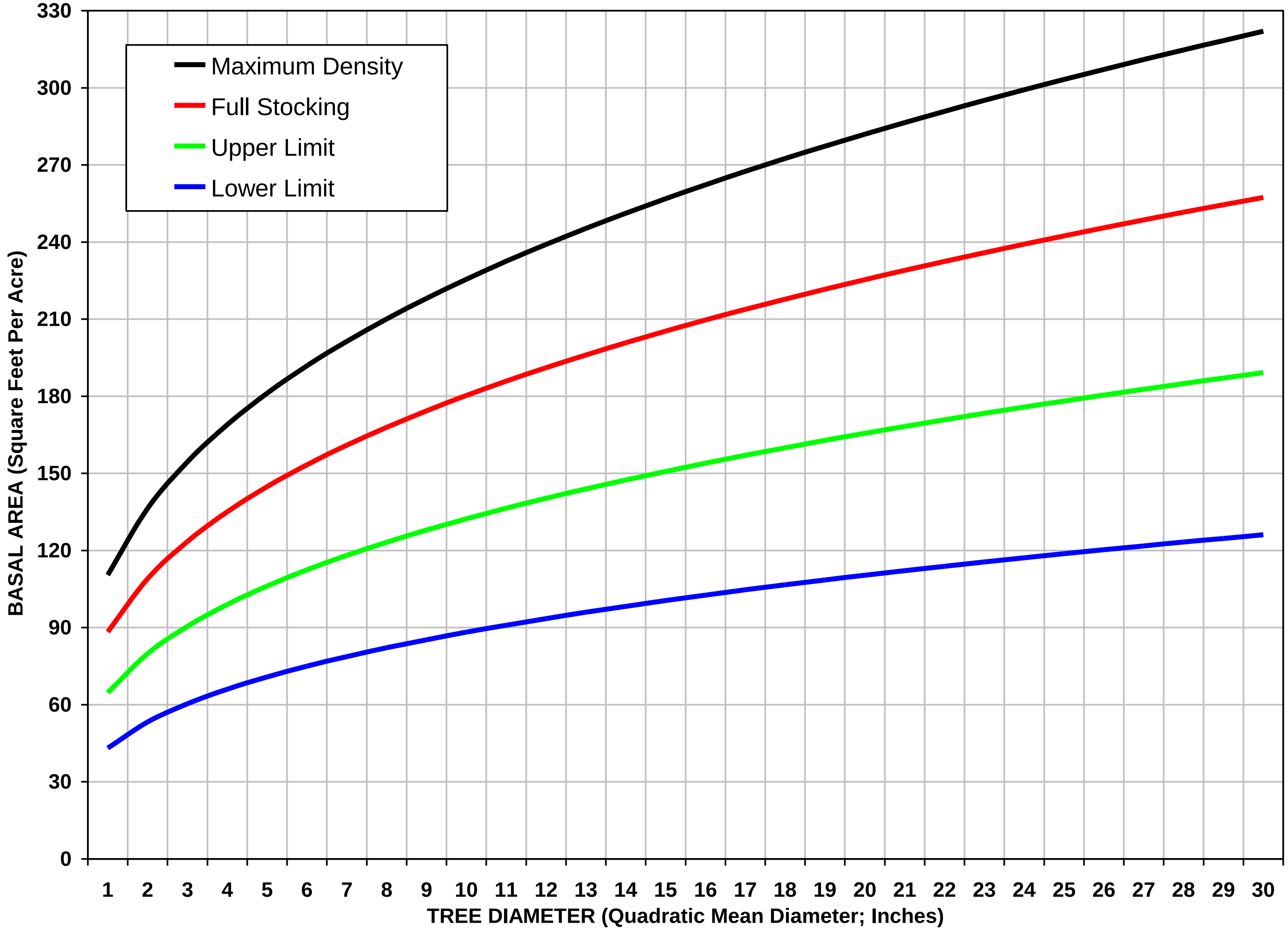

Figure 8 – Suggested stocking levels (basal area, ft^2/acre) for the moist upland forest PVG, and for a range of quadratic mean diameters, a mixed composition (30% Douglas-fir, 20% western larch, 20% lodgepole pine, 30% grand fir), and an irregular stand structure.

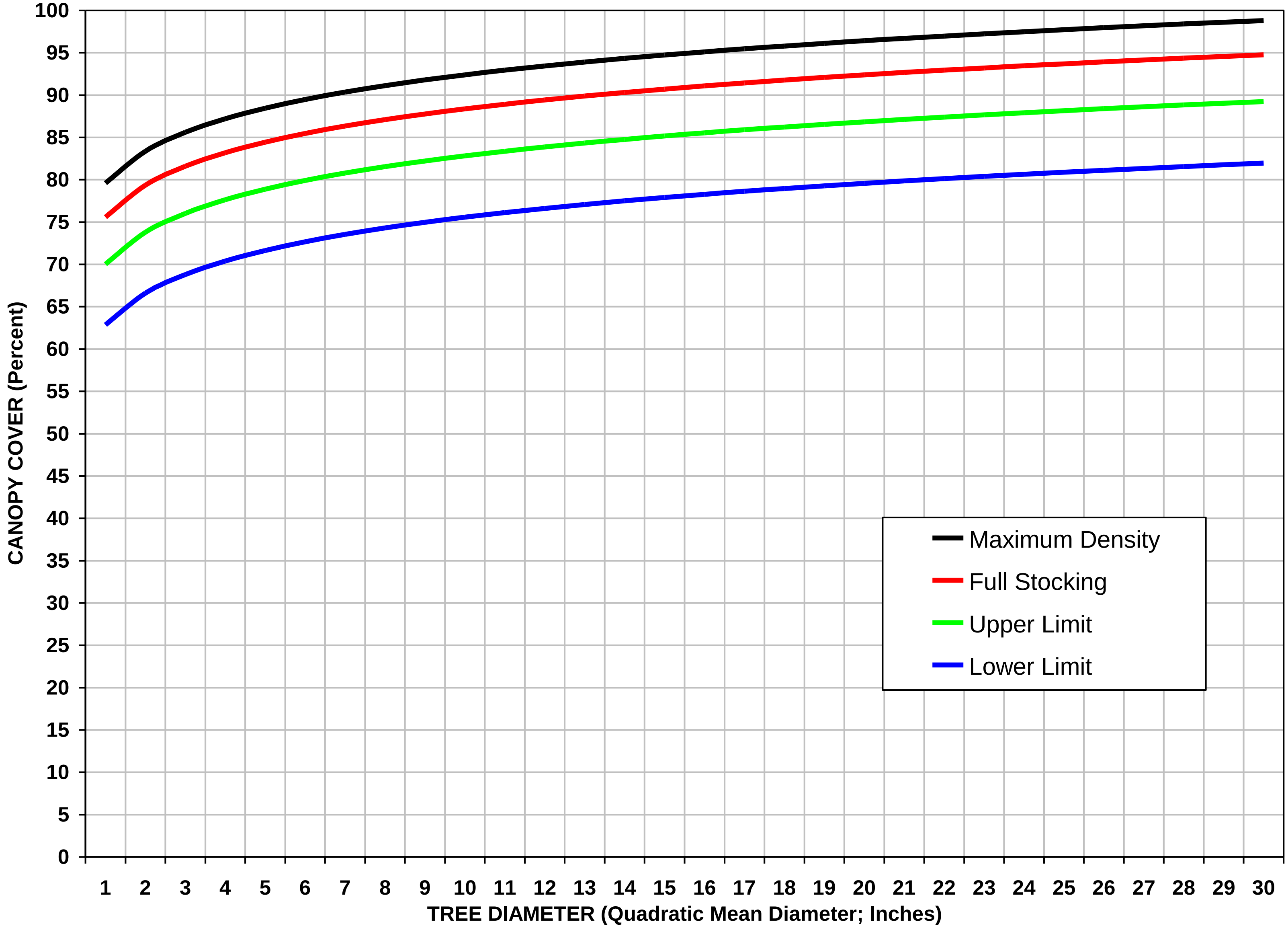

Figure 9 – Suggested stocking levels (canopy cover, percent) for the moist upland forest PVG, and for a range of quadratic mean diameters, a mixed composition (30% Douglas-fir, 20% western larch, 20% lodgepole pine, 30% grand fir), and an irregular stand structure.

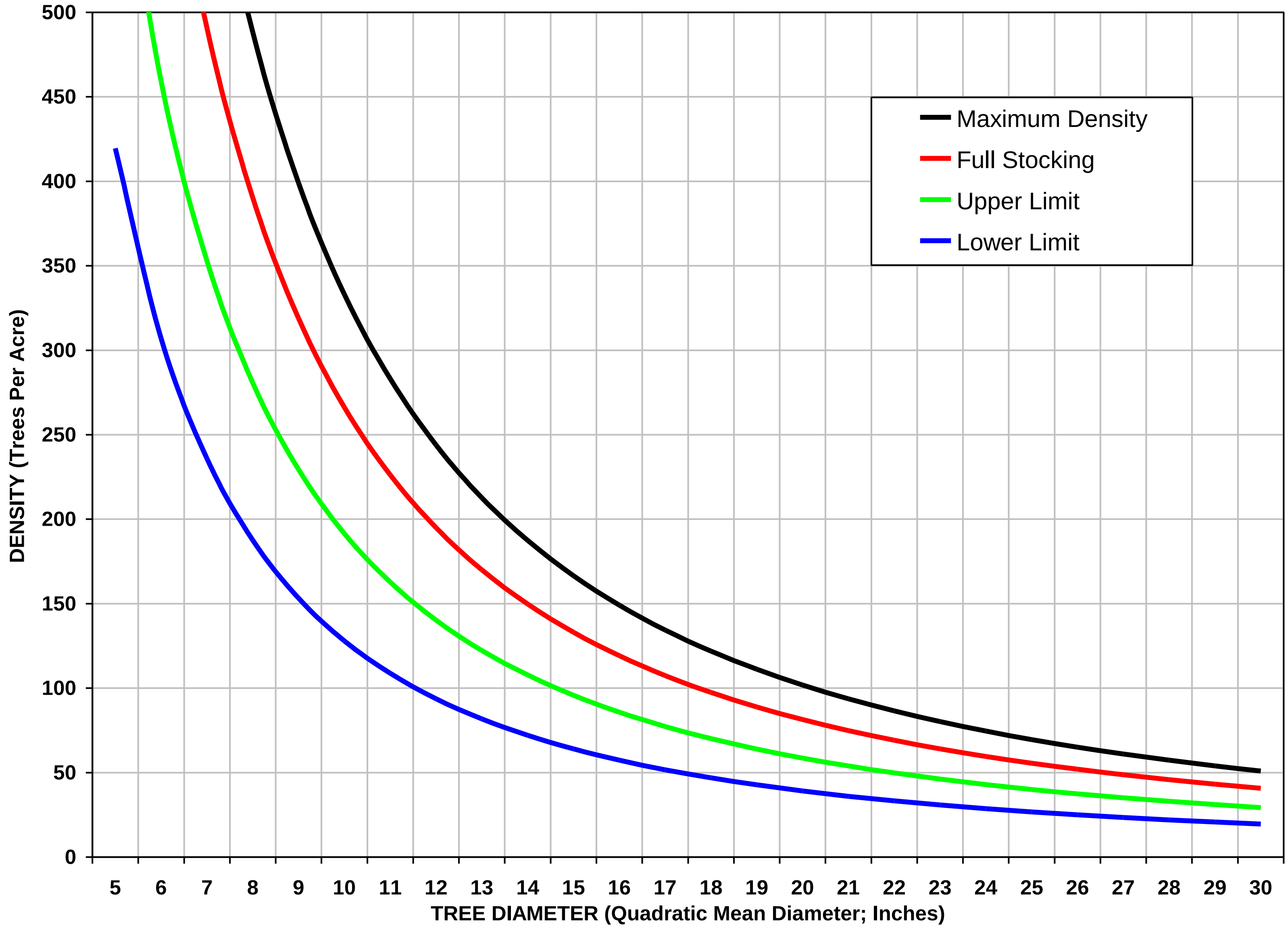

Figure 10 – Suggested stocking levels (trees/acre) for the cold upland forest PVG, and for a range of quadratic mean diameters, a mixed composition (10% Douglas-fir, 10% larch, 50% lodgepole pine, 10% subalpine fir, 20% spruce), and an irregular stand structure.

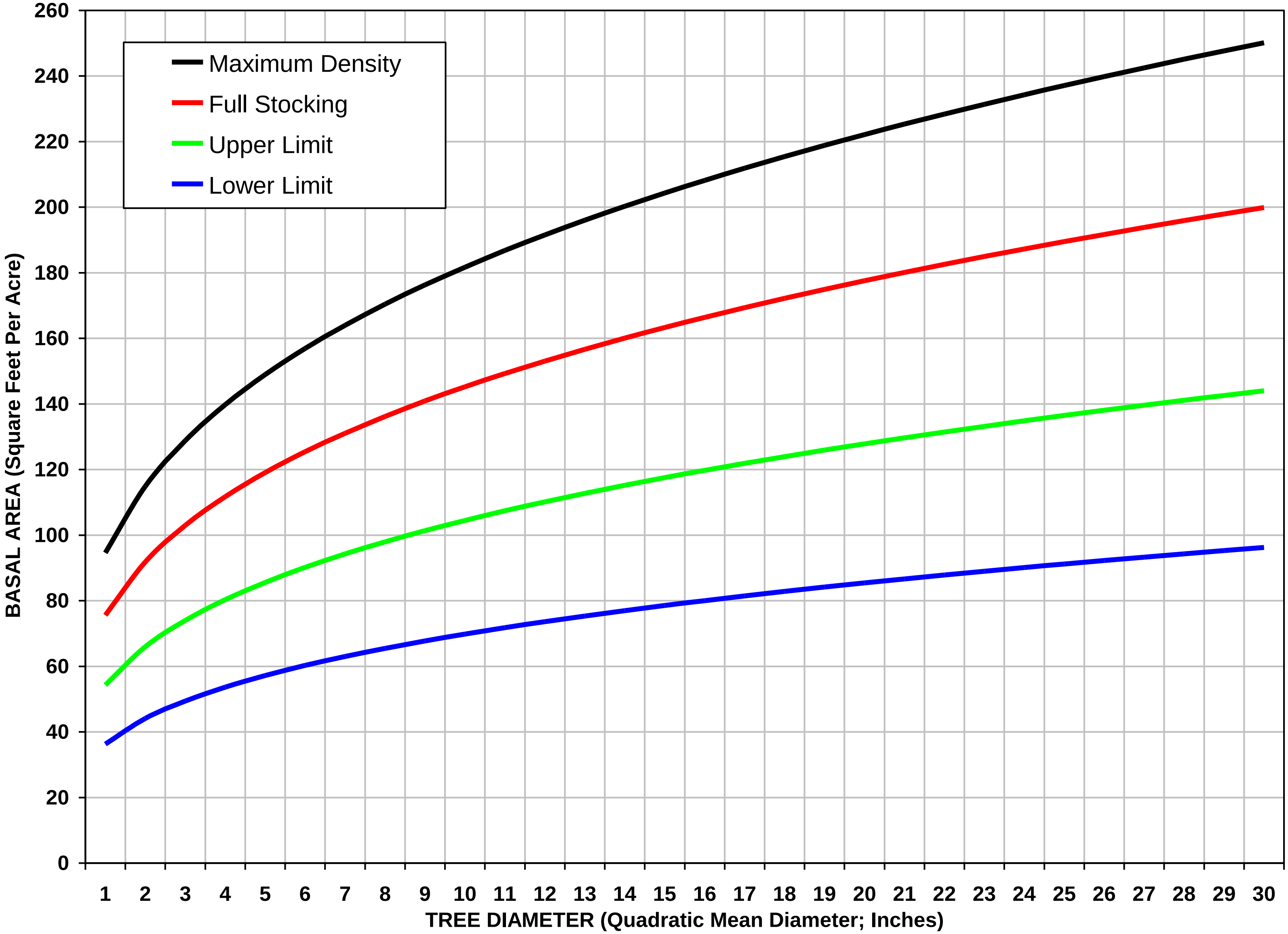

Figure 11 – Suggested stocking levels (basal area, ft^2/acre) for the cold upland forest PVG, and for a range of quadratic mean diameters, a mixed composition (10% Douglas-fir, 10% larch, 50% lodgepole, 10% subalpine fir, 20% spruce), and an irregular structure.

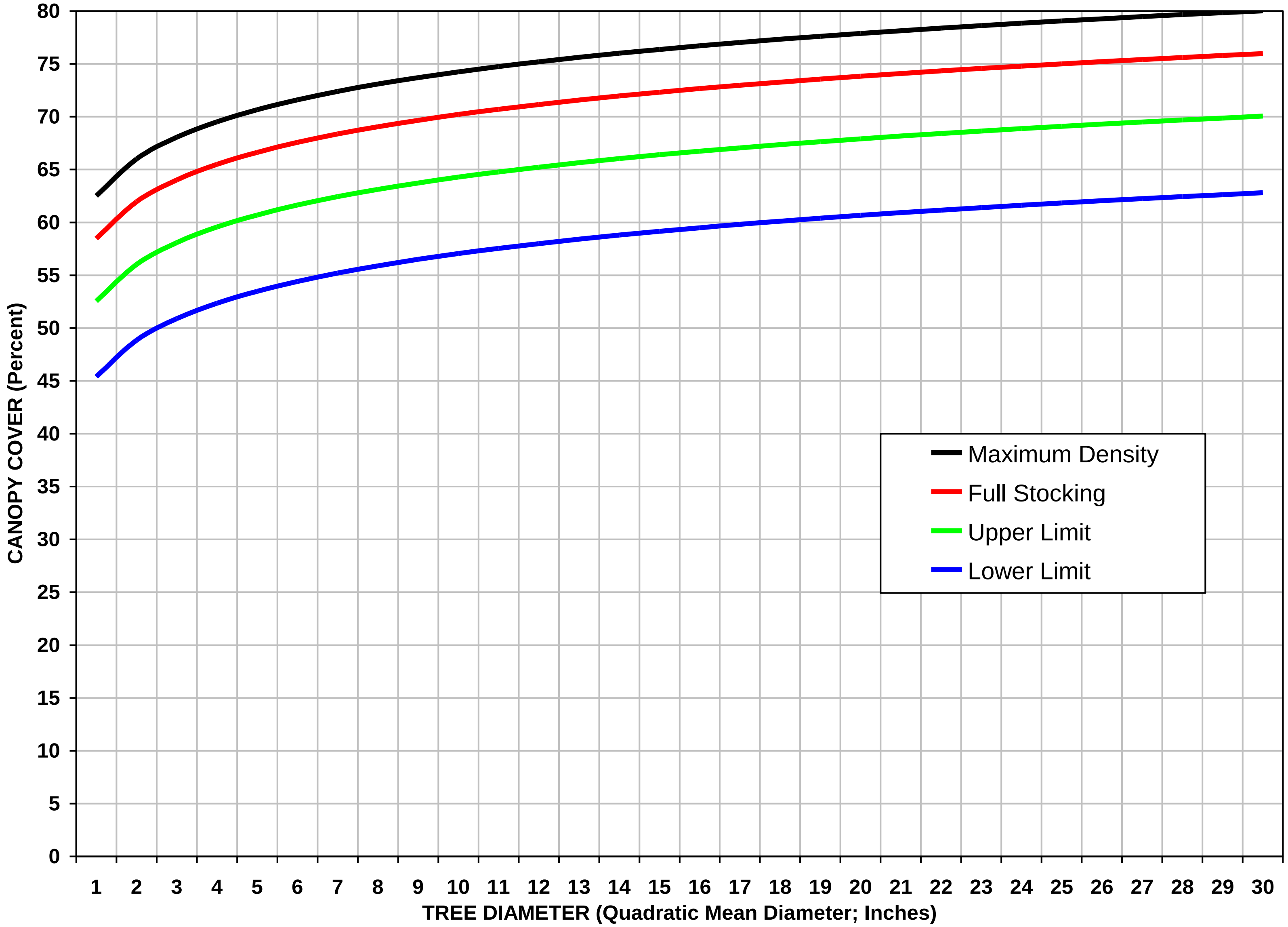

Figure 12 – Suggested stocking levels (canopy cover, percent) for the cold upland forest PVG, and for a range of quadratic mean diameters, a mixed composition (10% Douglas-fir, 10% larch, 50% lodgepole, 10% subalpine fir, 20% spruce), and an irregular structure.

GLOSSARY

Basal area. The cross-sectional area of a single tree stem, including the bark, measured at breast height (4½ feet above the ground surface on the upper side of the tree); also, the cross-sectional area of all stems in a stand and expressed per unit of land area (basal area per acre).

Canopy cover. The proportion of ground or water surface covered by a vertical projection of the outermost perimeter of the natural spread of foliage or plants, including small openings within the canopy. In some applications of this concept, total canopy cover can exceed 100 percent because the layering of different vegetative strata results in canopy covering the ground more than once. In other applications, the ground surface can only be obscured by foliage once and canopy cover can never exceed 100 percent.

Full stocking. A point in the development of even-aged stands in which differentiation has resulted in crown classes (Cochran et al. 1994); at full stocking, high stand density levels are causing intertree competition and resultant mortality of the weaker, less-vigorous trees (e.g., self thinning is occurring). Full stocking is analogous to normal density.

Irregular stand structure. A stand of trees characterized by variation in age structure or in the spatial arrangement of trees; stands without a uniform age or size structure.

Lower limit of full site occupancy. This threshold maintains sufficient stocking to allow a significant portion of a site's resources to be captured as tree growth. For the stocking information presented in this document, this threshold is also referred to as the lower limit of the management zone (Cochran et al. 1994, Powell 1999).

Lower limit of the management zone (LLMZ). A stocking level objective selected to coincide with the "lower limit of full site occupancy" threshold. For the stocking information presented in this document, the LLMZ was always set at 67 percent of the upper limit of the management zone for all combinations of tree species and plant association (Cochran et al. 1994).

Lower limit of self-thinning zone. This threshold refers to the stand development period where density is high enough to be causing competition-induced tree mortality (this period is called self thinning). For the stocking information presented in this document, this threshold is also referred to as the upper limit of the management zone (Cochran et al. 1994, Powell 1999).

Management zone. A stocking level zone established by setting upper and lower limits. For the stocking information presented in this document, the upper limit of the management zone is based on the "lower limit of self-thinning zone" threshold and the lower limit of the management zone is based on the "lower limit of full site occupancy" threshold.

Maximum density. The maximum stand density that can exist for a tree species for a given mean size in self-thinning populations (Long 1996). Maximum density is assumed to be 125% of full stocking (normal density) (Powell 1999).

Normal density. The stand density that is assumed to represent full site occupancy but which allows room for the development of crop trees; assumed to represent "average-maximum" competition or the average density of natural, undisturbed, fully-stocked stands. Normal density is assumed to be 80% of maximum density (Powell 1999).

Overstocked. Forestland stocked with more trees than normal or that full stocking would require (Dunster and Dunster 1996). In an overstocked stand, tree density is high enough that intertree competition is occurring and large trees are capturing growing space from small trees in a process called self-thinning.

Quadratic mean diameter. The diameter corresponding to the mean basal area; the diameter of a tree of average basal area in a stand.

Reference level. The absolute stand density that would normally be expected in a stand of given characteristics under some standard condition such as average maximum competition (Ernst and Knapp 1985). For the suggested stocking levels described in this document, full stocking (normal density or an "average-maximum" level of competition) was used as the reference level.

Relative density. The ratio, proportion or percent of absolute stand density to a reference level defined by some standard level of competition.

Self thinning. Plant mortality caused by intraspecific (inter-plant) competition in crowded, even-aged stands. For self-thinning populations, increasing average size is associated with a progressive diminution in tree density (Long and Smith 1984). Self thinning is also known as the $-^{3}/_{2}$ power rule, since the self-thinning zones for many plant species have a slope of $-^{3}/_{2}$ on a logarithmic graph (Westoby 1984).

Size class. A characterization of a vegetation layer's predominant situation with respect to tree size using diameter at breast height; a layer with a pole size class has a predominance of trees whose diameter is between 5 and 8.9 inches at breast height (breast height is defined as 4½ feet above the ground surface on the upper side of the tree).

Stand density. A quantitative measure of stocking expressed absolutely in terms of number of trees, basal area, or volume per unit area.

Stand density index. A widely used measure developed by Reineke (1933) that expresses relative density as the relationship between a number of trees per acre and a stand's quadratic mean diameter or QMD (SDI indexes density to a QMD of 10 inches).

Stocking. The amount of anything on a given area, particularly in relation to what is considered optimum; an indication of growing-space occupancy relative to a pre-established standard.

Upper limit of the management zone (ULMZ). A stocking level objective selected to coincide with the "lower limit of self-thinning zone" threshold. For the stocking information presented in this document, the ULMZ was set at 75 percent of full stocking (normal density) for each tree species except ponderosa and lodgepole pines, whose ULMZ values were established in a different way to reflect their susceptibility to mountain pine beetle (Cochran et al. 1994).

LITERATURE CITED

Cochran, P.H.; Geist, J.M.; Clemens, D.L.; Clausnitzer, R.R.; Powell, D.C. 1994. Suggested stocking levels for forest stands in northeastern Oregon and southeastern Washington. Res. Note PNW-RN-513. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 21 p.

Curtis, R.O. 1970. Stand density measures: an interpretation. Forest Science. 16(4): 403-414.

Daniel, T.W.; Meyn, R.L.; Moore, R.R. 1979. Reineke's stand density index in tabular form, in English and metric units, with its applications. Res. Rep. 37. Logan, UT: Utah State University, Utah Agricultural Experiment Station. 16 p.

Dunster, J.; Dunster, K. 1996. Dictionary of natural resource management. Vancouver, BC: UBC Press. 363 p.

Ernst, R.L.; Knapp, W.H. 1985. Forest stand density and stocking: concepts, terms, and the use of stocking guides. Gen. Tech. Rep. WO-44. Washington, OR: USDA Forest Service. 8 p.

Hall, F.C. 1998. Pacific Northwest ecoclass codes for seral and potential natural communities. Gen. Tech. Rep. PNW-GTR-418. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 290 p.

Helms, J.A., ed. 1998. The dictionary of forestry. Bethesda, MD: Society of American Foresters. 210 p.

Johnson, C.G., Jr.; Clausnitzer, R.R. 1992. Plant associations of the Blue and Ochoco Mountains. Tech. Pub. R6-ERW-TP-036-92. [Baker City, OR]: USDA Forest Service, Pacific Northwest Region, Wallowa-Whitman National Forest. 164 p.

Johnson, C.G., Jr.; Simon, S.A. 1987. Plant associations of the Wallowa-Snake province. Tech. Pub. R6-ECOL-TP-255b-86. [Baker City, OR]: USDA Forest Service, Pacific Northwest Region, Wallowa-Whitman National Forest. 272 p.

Long, J.N. 1985. A practical approach to density management. Forestry Chronicle. 61(2): 23-27.

Long, J.N. 1996. A technique for the control of stocking in two-storied stands. Western Journal of Applied Forestry. 11(2): 59-61.

Long, J.N.; Smith, F.W. 1984. Relation between size and density in developing stands: a description and possible mechanisms. Forest Ecology and Management. 7(3): 191-206. doi:10.1016/0378-1127(84)90067-7

Powell, D.C. 1999. Suggested stocking levels for forest stands in northeastern Oregon and southeastern Washington: an implementation guide for the Umatilla National Forest. Tech. Pub. F14-SO-TP-03-99. Pendleton, OR: USDA Forest Service, Pacific Northwest Region, Umatilla National Forest. 300 p.

Powell, D.C. 2000. Potential vegetation, disturbance, plant succession, and other aspects of forest ecology. Tech. Pub. F14-SO-TP-09-00. Pendleton, OR: USDA Forest Service, Pacific Northwest Region, Umatilla National Forest. 88 p.

Powell, D.C. 2004. Description of composite vegetation database. White Pap. F14-SO-WP-Silv-2. Pendleton, OR: USDA Forest Service, Pacific Northwest Region, Umatilla National Forest. 37 p.

Powell, D.C.; Johnson, C.G., Jr.; Crowe, E.A.; Wells, A.; Swanson, D.K. 2007. Potential vegetation hierarchy for the Blue Mountains section of northeastern Oregon, southeastern Washington, and west-central Idaho. Gen. Tech. Rep. PNW-GTR-709. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 87 p.

REO (Regional Ecosystem Office). 1995. Ecosystem analysis at the watershed scale: federal guide for watershed analysis. Version 2.2. Portland, OR: Regional Ecosystem Office. 26 p.

Reineke, L.H. 1933. Perfecting a stand-density index for even-aged forests. Journal of Agricultural Research. 46(7): 627-638.

Westoby, M. 1984. The self-thinning rule. Advances in Ecological Research. 14: 167-225.

APPENDIX 1: SILVICULTURE WHITE PAPERS

White papers are internal reports, and they are produced with a consistent formatting and numbering scheme – all papers dealing with Silviculture, for example, are placed in a silviculture series (Silv) and numbered sequentially. Generally, white papers receive only limited review and, in some instances pertaining to highly technical or narrowly focused topics, the papers may receive no technical peer review at all. For papers that receive no review, the viewpoints and perspectives expressed in the paper are those of the author only, and do not necessarily represent agency positions of the Umatilla National Forest or the USDA Forest Service.

Large or important papers, such as two papers discussing active management considerations for dry and moist forests (white papers Silv-4 and Silv-7, respectively), receive extensive review comparable to what would occur for a research station general technical report (but they don't receive blind peer review, a process often used for journal articles).

White papers are designed to address a variety of objectives:

(1) They guide how a methodology, model, or procedure is used by practitioners on the Umatilla National Forest (to ensure consistency from one unit, or project, to another).

(2) Papers are often prepared to address ongoing and recurring needs; some papers have existed for more than 20 years and still receive high use, indicating that the need (or issue) has long standing – an example is white paper #1 describing the Forest's big-tree program, which has operated continuously for 25 years.

(3) Papers are sometimes prepared to address emerging or controversial issues, such as management of moist forests, elk thermal cover, or aspen forest in the Blue Mountains. These papers help establish a foundation of relevant literature, concepts, and principles that continuously evolve as an issue matures, and hence they may experience many iterations through time. [But also note that some papers have not changed since their initial development, in which case they reflect historical concepts or procedures.]

(4) Papers synthesize science viewed as particularly relevant to geographical and management contexts for the Umatilla National Forest. This is considered to be the Forest's self-selected 'best available science' (BAS), realizing that non-agency commenters would generally have a different conception of what constitutes BAS – like beauty, BAS is in the eye of the beholder.

(5) The objective of some papers is to locate and summarize the science germane to a particular topic or issue, including obscure sources such as master's theses or Ph.D. dissertations. In other instances, a paper may be designed to wade through an overwhelming amount of published science (dry-forest management), and then synthesize sources viewed as being most relevant to a local context.

(6) White papers function as a citable literature source for methodologies, models, and procedures used during environmental analysis – by citing a white paper, specialist reports can include less verbiage describing analytical databases, techniques, and so forth, some of which change little (if at all) from one planning effort to another.

(7) White papers are often used to describe how a map, database, or other product was developed. In this situation, the white paper functions as a 'user's guide' for the new product. Examples include papers dealing with historical products: (a) historical fire extents for the Tucannon watershed (WP Silv-21); (b) an 1880s map developed from General Land Office survey notes (WP Silv-41); and (c) a description of historical mapping sources (24 separate items) available from the Forest's history website (WP Silv-23).

The following papers are available from the Forest's website: [Silviculture White Papers]

Paper #	Title
1	Big tree program
2	Description of composite vegetation database
3	Range of variation recommendations for dry, moist, and cold forests
4	Active management of dry forests in the Blue Mountains: silvicultural considerations
5	Site productivity estimates for upland forest plant associations of the Blue and Ochoco Mountains
6	Fire regimes of the Blue Mountains
7	Active management of moist forests in the Blue Mountains: silvicultural considerations
8	Keys for identifying forest series and plant associations of the Blue and Ochoco Mountains
9	Is elk thermal cover ecologically sustainable?
10	A stage is a stage is a stage…or is it? Successional stages, structural stages, seral stages
11	Blue Mountains vegetation chronology
12	Calculated values of basal area and board-foot timber volume for existing (known) values of canopy cover
13	Created openings: direction from the Umatilla National Forest land and resource management plan
14	Description of EVG-PI database
15	Determining green-tree replacements for snags: a process paper
16	Douglas-fir tussock moth: a briefing paper
17	Fact sheet: Forest Service trust funds
18	Fire regime condition class queries
19	Forest health notes for an Interior Columbia Basin Ecosystem Management Project field trip on July 30, 1998 (handout)
20	Height-diameter equations for tree species of the Blue and Wallowa Mountains
21	Historical fires in the headwaters portion of the Tucannon River watershed
22	Range of variation recommendations for insect and disease susceptibility
23	Historical vegetation mapping
24	How to measure a big tree
25	Important insects and diseases of the Blue Mountains
26	Is this stand overstocked? An environmental education activity

Paper #	Title
27	Mechanized timber harvest: some ecosystem management considerations
28	Common plants of the south-central Blue Mountains (Malheur National Forest)
29	Potential natural vegetation of the Umatilla National Forest
30	Potential vegetation mapping chronology
31	Probability of tree mortality as related to fire-caused crown scorch
32	Review of the “Integrated scientific assessment for ecosystem management in the interior Columbia basin, and portions of the Klamath and Great basins” – forest vegetation
33	Silviculture facts
34	Silvicultural activities: description and terminology
35	Site potential tree height estimates for the Pomeroy and Walla Walla ranger districts
36	Tree density protocol for mid-scale assessments
37	Tree density thresholds as related to crown-fire susceptibility
38	Umatilla National Forest Land and Resource Management Plan: forestry direction
39	Updates of maximum stand density index and site index for the Blue Mountains variant of the Forest Vegetation Simulator
40	Competing vegetation analysis for the southern portion of the Tower Fire area
41	Using General Land Office survey notes to characterize historical vegetation conditions for the Umatilla National Forest
42	Life history traits for common conifer trees of the Blue Mountains
43	Timber volume reductions associated with green-tree snag replacements
44	Density management field exercise
45	Climate change and carbon sequestration: vegetation management considerations
46	The Knutson-Vandenberg (K-V) program
47	Active management of quaking aspen plant communities in the northern Blue Mountains: regeneration ecology and silvicultural considerations
48	The Tower Fire…then and now. Using camera points to monitor postfire recovery
49	How to prepare a silvicultural prescription for uneven-aged management
50	Stand density conditions for the Umatilla National Forest: a range of variation analysis
51	Restoration opportunities for upland forest environments of the Umatilla National Forest
52	New perspectives in riparian management: Why might we want to consider active management for certain portions of riparian habitat conservation areas?
53	Eastside Screens chronology
54	Using mathematics in forestry: an environmental education activity
55	Silviculture certification: tips, tools, and trip-ups

Paper #	Title
56	Vegetation polygon mapping and classification standards: Malheur, Umatilla, and Wallowa-Whitman national forests
57	The state of vegetation databases on the Malheur, Umatilla, and Wallowa-Whitman national forests

REVISION HISTORY

February 2013: minor formatting and editing changes were made; appendix 1 was added describing the white paper system, including a list of available white papers.